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Best Management Practices Guidance
Discharge of Dredged or Fill Materials

Environmental Protection Agency
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Best Management Practices Guidance, Discharge of Dredged or Fill Materials

Placement of Fill Materials

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SUBJECT: Transmittal of Document Entitled "Best Management Practices Guidance, Discharge of Dredged or Fill Materials"

FROM : Swep T. Davis, Deputy Assistant Administrator
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TO : All Regional Water Division Directors
ATTN: All Regional 208 Coordinators
All Regional 404 Coordinators
All Regional NPS Coordinators
All State and Areawide Water Quality Management Agencies
Other Concerned Groups

TECHNICAL GUIDANCE MEMORANDUM - TECH - 50

Purpose

This "Best Management Practices Guidance" document has been prepared to provide State and areawide water quality management agencies, other State and Federal agencies, and the concerned public with information on readily-available processes, procedures, methods, and techniques that can be used to minimize or prevent environmental impacts that could result from the discharge of dredged or fill materials. It has been written in a manner that makes it easy to follow so that the reader does not have to be an expert in the discipline to be able to understand what the problems are and some of the solutions that are presently available.

Guidance

The document is the latest provided in accordance with policies and procedures of 40 CFR, Part 131 which states that "EPA will prepare guidelines concerning the development of water quality management plans to assist States and areawide planning agencies in carrying out the provisions of these regulations." Management regulations being drafted for Statewide dredged and fill discharge programs under 40 CFR 35.1570 state that "Any BMP's developed by a Statewide dredged and fill program, certified as appropriate for inclusion in a State 404 permit, and accepted by the Regional Administrator for those purposes must be included in a State 404 permit, when they are not less stringent than other requirements in the 404 permit."

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16. ABSTRACT

Before any decisions can be made regarding the discharge of dredged or fill materials into waters of the United States, all probable impacts and feasible alternative sites must be considered. This will include evaluation of such factors as the necessity for discharges; sensitivity of the area to environmental impacts, both long and short term; possible alternative sites or a scheduling of operations; and effectiveness of available site-specific Best Management Practices to prevent, or minimize the impacts. Discharges of dredged of fill materials must comply with guidelines prepared by the Administrator of EPA pursuant to Section 404 (b) (1) of Public Law 95-217.

This "Best Management Practices Guidance" document has been prepared to provide State and areawide water quality management agencies, other State and Federal agencies, and the concerned public with information on readily-available processes, procedures, methods, and techniques that can be used to minimize or prevent environmental impacts that could result from the discharge of dredged of fill materials. It has been written in a manner that the reader does not have to be an expert in the discipline to be able to understand what the problems are and some of the solutions that are presently available.

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BEST MANAGEMENT PRACTICES GUIDANCE,
DISCHARGE OF DREDGED OR FILL MATERIALS

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WASHINGTON, D.C. 20460

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3. Department of the Army, Corps of Engineers
4. Department of Energy
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6. Department of Transportation, Federal Highway Administration
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PREFACE

Before any decision can be made regarding the discharge of dredged or fill materials into waters of the United States, all probable impacts and feasible alternative sites must be considered. This will include an evaluation of such factors as the necessity for discharges; sensitivity of the area to environmental impacts, both long and short term; possible alternative sites or a scheduling of operations; and effectiveness of available site-specific Best Management Practices to prevent, or minimize, the impacts. Discharges of dredged of fill materials must comply with guidelines prepared by the Administrator of EPA pursuant to Section 404(b)(1).

Section 404 Of the Federal Water Pollution Control Act, as Amended (33 U.S.C. 466 et seq.) establishes a permit program for the regulation of discharges of dredged or fill materials into the waters of the United States. The Section 404 permit program is currently administered by the U.S. Army Corps of Engineers. Sections 404(g) and (h) provide that, upon approval by the Administrator of EPA, a State may administer its own individual and general permit program to control discharges of dredged or fill material. Approved State Section 404 programs regulate the discharge of dredged or fill in all waters and adjacent wetlands of the State except for those which are "...presently used or susceptible to use in their natural condition or by reasonable improvement as a means to transport interstate or foreign commerce..." The Corps of Engineers, in all cases, administers the Section 404 program in such commercially navigable waters.

The Act further authorizes states with approved statewide regulatory programs under Section 208(b)(4) to regulate certain discharges of dredged or fill materials through those programs in lieu of the Section 404 permit program. Actions regulated by a statewide 208(b)(4) program must be those which EPA has designated as appropriate for this alternative method of regulation, and for which specific Best Management Practices criteria have been developed by the State and approved by EPA.

The guidance presented in this document on dredged and fill activities was developed to provide the State 208 and 404 agencies, other State agencies, Federal organizations,and other concerned groups with the most readily available general information on how adverse environmental impacts resulting from certain discharges of dredged or fill materials can be prevented, or minimized, through the use of Best Management Practices (BMP's). The BMP's in this guidance are intended to support legal requirements in Section 404 and 208(b)(4) programs, but do not constitute requirements unless they are made part of a permit or regulatory program.

A multi-disciplinary approach is critical for adequate evaluation of the discharge and determination of appropriate BMP's. competent geologists, biologists or wildlife specialists, engineers, hydrologists, soil scientists, and other personnel from 208 and 404 management agencies as well as involved Federal and State fish and game, water resource, and conservation agencies should be consulted. Their opinions and views should be obtained and evaluated and the long-term as well as short-term results of the activities and projects considered.

The types of pollution control measures described here and included under the term "Best Management Practices" will usually be designed, in accordance with site-specific conditions, by dischargers and, subject to approval under criteria established by a responsible State management agency, applied under a 208 regultory program. They also may be specified, along with appropriate design criteria, as conditions within issued State 404 permits.

Determination of whether to implement dredged or fill Best Managment Practices through a 208 regulatory program or a State 404 permit program are to be based primarily upon changes in the use of areas of navigable waters and the impacts of proposed activities upon water flow, circulation, and the reach of the water bodies. Where the use has been changed, the flow or circulation impaired, or the reach of the water body reduced, regulation under Section 208 is precluded. Under these conditions, BMP's must be implmented under the 404 permit program (Section 404 (f)(2)). The review requirements of this permit program will ensure that all possible data, opinions, and evaluations are obtained prior to the decision of whether, and on what terms, the project is to be authorized. There will be more assurance through this program that adverse impacts resulting from the activities will be detected and identified and that criteria for design and effective application of a BMP system, or other protective measures, will be optimized. If conditions existing at either a proposed site, or at a practical alternative site, for discharging dredged or fill materials are so sensitive that available BMP's or other mitigating features will not reduce environment degradation to acceptable levels, the discharge must be prohibited.

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GUIDANCE FOR BEST MANAGEMENT PRACTICES TO CONTROL THE DISCHARGE OF DREDGED OR FILL MATERIALS

INTRODUCTION

The discharge of dredged or fill materials involves man's introduction of what can be considered principally naturally-occurring sedimentary deposits, rocks, or earthen materials into waters and adjacent wetlands of the United States. Dredged materials generally are discharged for disposal purposes while fill materials are placed to provide for engineering structures of one kind or another.

Although fill generally consists of natural geologic materials it can be made up of masses of concrete, wood, or any other substances used to displace the water and change bottom surface elevations. Fill materials are placed into wetlands or water bodies to provide adequate foundations, at required elevations, for municipal, industrial, commercial, recreational, or residential development or structures. They can form bridge approaches, portions of causeways, dams, dikes, levees, fills for roads across stream channels, and artificial islands or reefs; function to protect property from erosion by stream or wave action through the use of groins, rip rap blankets, revetments, breakwaters, and structural walls of one type or another; and fullfill other useful purposes. Materials dredged from a water body can become fill materials if they are used for providing adequate sites for structures. They could include small linear backfills in excavations for subaqueous utility lines or communication cables and fills of larger areal extent in low lands to provide surface elevations high enough for construction purposes.

Analysis of the Problem

Streams, wetlands, lakes, and other water bodies can accept, accommodate, or adapt to certain stress conditions caused by the discharge or placement of dredge or fill materials. Exceeding these conditions will cause readjustments to take place in natural processes which can initiate water pollution or other undesirable effects. Stresses imposed by the discharge of dredged and fill materials into an aquatic environment can be induced by or result from:

1. Changes in the natural flow or circulation of surface and/or subsurface waters.
2. The addition of pollutants into the water in excess quantities to cause changes in the chemical or physical characteristics of the waters.
3. Alterations of the elevation of the substrate, or bottom of the water body.
4. Changes in key ecological relationships and interdependencies
5. Permanent loss of part of the aquatic environment through conversion to dry land.

The stresses are interrelated and can be superimposed upon one another to severely damage, or even destroy wetlands or water bodies. Masses, or accumulations, of discharged dredged or fill materials often cause detrimental changes in the flow or circulation of waters. They change substrate, or bottom elevations, and obstruct or restrict the flow of surface waters or ground waters by reducing the cross-sectional areas through which they flow. Local or areawide changes in water levels, normal fluctuations, velocities, directions of movements, and other characteristics occur. They can initiate adverse effects in the production, movement, and occurrence of terrestial and aquatic wildlife; cause changes in the chemical and physical quality and other characteristics of the water; and function to increase normal erosion and sediment transport and deposition rates. The particles of various sizes that comprise the principal mass of dredged and fill materials (sediments) can become pollutants if moving water erodes them from their area of placement and transports them into adjacent areas. They can reduce the light-transmitting capacity of the water body to create undesirable environmental effects, blanket its bottom to smother or reduce aquatic life, and impair its quality for beneficial uses.

Dredged materials often contain additional pollution-causing materials such as nutrients, metallic compounds, pesticides, oils, and greases, or other materials. Many of them are adsorbed to the fine-grained dredged material such as silts and clays. Others form coatings on materials of any size. Fill materials may contain pollutants similar to those in the dredged materials if they are obtained from a polluted source. Even if they are obtained from a source that has not been affected by pollutants, fill materials may contain naturally-occurring substances that change status and become pollutants when transported to and placed into a different environment, particularly an aquatic one. These substances may include such mineral compounds as iron sulfide (pyrite), calcium sulfate, sodium chloride, and other materials which, through chemical or physical processes, can become soluble and be transported into adjacent area.

Some pollutants, such as nutrients, can cause accelerated eutrophication (enrichment) of waters with accompanying detrimental changes in aquatic life. Others can change the physical or chemical characteristics of the water, impart undesirable tastes to it and the aquatic life in it, and initiate undesirable environmental effects in the life cycle of all aquatic organisms and wildlife depending on it. As higher order organisms consume lower aquatic organisms that have ingested minor quantities of pollutants, concentration of the pollutants may occur in the higher organisms. This is termed bio-magnification. Its severity is influenced by the physiology of the organisms involved and the characteristics of the pollutants. (See Figure No. 0-1).

BIOLOGICAL MAGNIFICATION

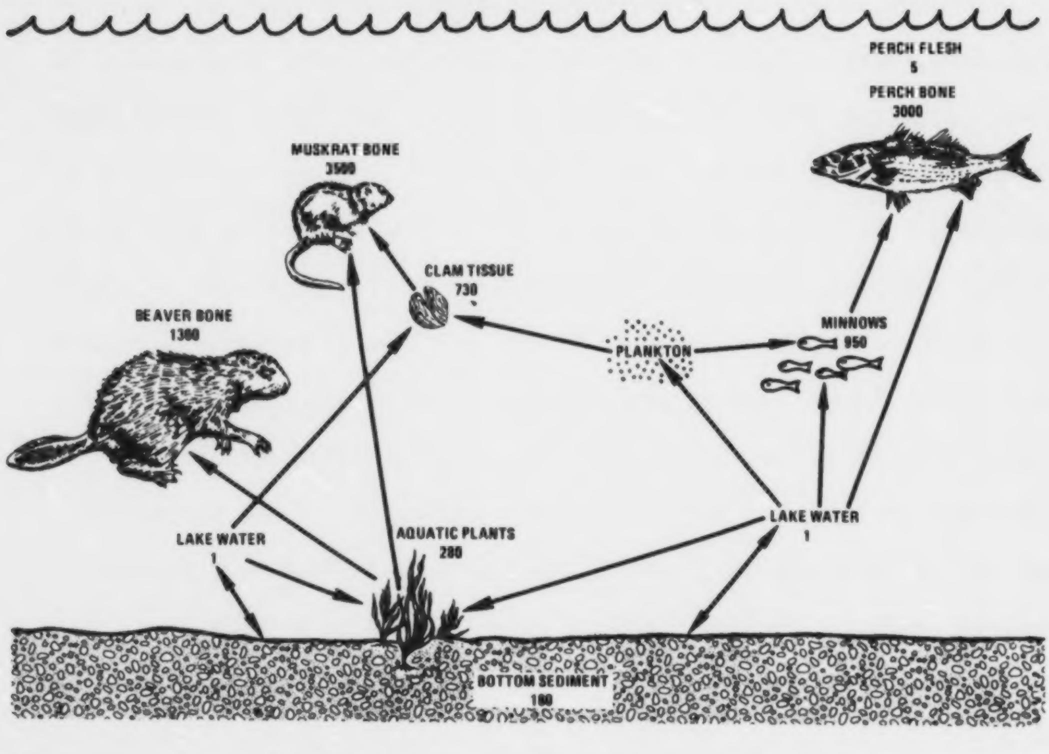

PERCH FLESH
5
PERCH BONE
3000
MUSKRAT BONE
3500
CLAM TISSUE
730
BEAVER BONE
1300
PLANKTON
MINNOWS
950
LAKE WATER
1
AQUATIC PLANTS
280
LAKE WATER
1
BOTTOM SEDIMENT
100

Figure No. 0-1 - Biological Concentration of Strontium - 90
The Average Concentration Factors for Strontium - 90
In the Perch Lake food web. (Adapted from Ophel, I.L.
"The Fate of Radiostrontium in Freshwater Community
Source" in Radioecology, 1963).

Adequate Program Planning and Development

Advanced planning, conducted prior to initiating the discharge or placement of dredged or fill materials into a stream and adjacent wetlands, is essential for preventing environmental problems. Often, it can prevent, through management decisions, the development of conditions that could add materially to the potential for environmental degradation. If problems can be foreseen during the planning stages, alternative sites, scheduling of operations, methods, or practices may be used to minimize them. Program planning and development probably will be done most advantageously on a multi-disciplinary type approach. Personnel with engineering, geologic, wildlife and biologic, soils, and hydrologic backgrounds should all be involved in the process to enable all possible aspects of the problems and their solutions to be considered. If personnel competent in any of these disciplines are needed and not available in the staff of the management agency, they may be obtained, on a consulting basis or some other type of arrangement, from one of the various Federal, State,or local agencies that are knowledgeable in the field.

All necessary pertinent information on the proposed disposal site, and alternative sites, should be collected and evaluated. Factors to be considered include the existing environmental conditions, potential for the discharge to cause pollution, and Best Management Practices for pollution prevention or reduction. The best combination of sites, types of discharges, and management practices should be selected and implemented to minimize the environmental problems that could result from the activities. Sites in which very severe environmental problems could arise should be avoided.Usually, minor changes prior to initiating an activity will serve to prevent pollution problems or habitat destruction much more effectively than remedial measures.

An adequate pollution control program for preventing environmental problems that could result from the discharge of dredged or fill materials can best be achieved through the proper development of plans by the discharger; adequate review and approval of these plans by a responsible management agency; adjustment of the plans after the review to maximize the effectiveness of the Best Management Practices; implementation of the BMP's; monitoring by the management agency for adherence to the plan; and, when required, effective and aggressive enforcement of violations of environmental laws.

Effective Best Management Practices must be based upon a consideration of all existing conditions at the site that interrelate to maintain the long-term integrity of the local environment. They should achieve required environmental protection at the least possible cost. Important factors to consider in their development include the occurrence and movement of both ground and surface water; geologic, soils, and topographic conditions; and the existence, needs, and sensitivities of aquatic and other wildlife occurring in the area. Proper scheduling, or timing of activities, often is as important to a Best Management Practice as an adequate design and application.

Guidance for the development, selection, and application of Best Management Practices, such as those presented in this document, can be provided by governmental agencies. On a national scale it must be general in nature such as that provided in this document. At the State, and possibly local level, the guidance will be more specific regarding local conditions.

The BMP's defined in site plans, however, must be developed and designed on a site-specific basis by those most familiar and knowledgeable regarding the site area.

Guidance should always be flexible enough to allow initiative to be used for developing new, less expensive, and more effective BMP's. A flexible BMP program also allows for the application of State and local expertise towards the understanding of site-specific environmental characteristics and problems. This is essential as official guidelines often are interpreted to represent minimum standards. These standards, in reality, then tend to become enforceable criteria for performance. As long as the guidance does not become too rigid and management agencies do not begin to feel that it covers all site-specific requirements that are to be encountered, the approach is good. If, for a management agency, the guidance represents a "cookbook" to use in lieu of good professional and management experience and judgement, it will become a poor tool. They must ensure that rote and complacency do not begin to supersede the use of logic and common sense in the development and use of Best Management Practices.

Best Management Practices, Summary

Best Management Practices for preventing environmental impacts from the discharge of dredged or fill materials into waters of the United States are, to a large extent, technically feasible and available. After all alternatives to a project have been evaluated, based upon 404(b)(1) guidelines, and the decision has been made that the discharge, or placement of dredged or fill material is to be conducted, effective procedures, measures, and practices for preventing environmental problems can be devised and implemented. They involve practical engineering designs, structures, procedures, and schedules for operations adapted from those that have been developed and used for many years to control surface or subsurface flows of water, prevent the loss of materials from a site area, and provide for the protection and propagation of fish, shellfish and wildlife. The specific characteristics of the site must be evaluated and considered critically before finalizing BMP's to be applied or used.

Since many of the environmental concerns we have now were not of vital interest during the conduct of past engineering projects, many of the existing techniques and structures are inadequate for environmental protection or create, rather than prevent, such problems. In view of this, modification of the design of many structures and the procedures for their placement or construction are essential to reverse this trend and protect the environment rather than damage it.

Environmental problems that could result from the discharge of dredged or fill materials into streams, estuaries, lakes, or wetlands can be prevented or minimized through implementation of effective Best Management Practices. Descriptions, discussions, and examples of BMP's are presented in the following five chapters of this guidance document. They include, but are not limited to operating procedures, scheduling of activities, or management practices which can be conducted or applied to ensure that: (1) stream or current flow changes are not adversely affected, (2) increased sediment loads or turbidity levels are effectively reduced, and (3) other pollutants included with dredged or fill materials are restricted from entering water bodies. BMP's may also involve (4) protecting existing habitat and providing for fish and wildlife propagation and (5) the relocation, reconstruction, or enhancement of an area of wetlands or a stream if a significant portion of the water body will be affected and no other alternative exists.

Best Management Practices involving singular minor discharges of dredged or fill materials with relatively insignificant impacts on the aquatic environment are similar to those needed for major discharges with significant impacts. They are much less elaborate and expensive, however, and generally require no formal design or rigid application specifications. It must be emphasized here that the results desired with regard to the protection of the chemical biological, and physical integrity of our Nation's waters are the same with either large or small discharges.

Preventing Impairment of Water Flow or Circulation

Masses of dredged or fill materials placed (or discharged) into streams, lakes, or wetlands can impair the natural movement or circulation of water. The degree of impairment will depend upon the volume, permeability, and location of the material that is discharged where it can reduce the cross sectional area through which the water flows. This applies to the sub-surface flow of water as well as to surface movement. A permit for discharge may be required in accordance with Section 404 if flow or circulation will be impaired and the BMPs implemented as a requirment of this program.

There are several ways to reduce, or prevent, the impairment of circulation or flow. They involve one or more of the following basic techniques regarding discharge, or placement, of dredged or fill materials:

1. Minimizing the extent of individual fills or the concentration or numbers of fills.
2. Providing continous open channels through, or around, masses of materials parallel to natural flow directions.
3. Using alternate sections of impervious fill with pervious sections or open structures to permit free flow of water.

4. Designing channel - spanning structures:
   a. To pass flood flows with no significant adverse impacts from flow restriction.
   b. To minimize debris or other blockage which can obstruct flow.
   c. In accordance with upstream and downstream hydraulic flow conditions (do not cause drastic changes in flow regime).
5. Aligning bridges, culverts, and other structures to limit adverse impacts from flow disruption resulting from abutments or other fills.

Preventing, or Controlling, The Runoff of Excess Sediment Loads or Turbidity Increases

Excess sediment loads or turbidity increases can occur as a result of the placement of dredged or fill materials into water bodies and wetlands. The erosion and transportation of particulates can take place during the actual placement of the dredged and fill materials if no preventive measures such as cofferdams, caissons, filter cloth fences, or other preventive devices or procedures are used. To prevent in-place, or completed, dredged or fill deposits from being subjected to the erosive forces of high-velocity surface flows, effective surface protection measures such a rip rap blankets (or layers), concrete walls, and similar measures should be provided. The erosion and transport of sediments can be minimized, or prevented,by one or more of the following measures or practices:

1. Placing materials on dry land by scheduling operations during low flows, using structures to exclude the water, or by temporarily diverting the stream from the site.

2. Protecting slopes that will be subject to erosion by surface flows with erosion-resisting coverings such as vegetation, rip rap blankets (with or without underlying filters), gabions, retaining walls, aprons, wing walls, and similar measures.
3. Designing bridge-supporting members such as piers, piles, eto., to minimize scour.
4. Providing filter cloth, or some other type of filtering media to remove sediment being transported from an area of placement.
5. Avoiding placement of dredged or fill material during conditions that may be critical for sensitive aquatic life and wildlife such as spawning seasons or migration times.
6. Using placement procedures to prevent, or restrict, the movement of mobile equipment in the water. Equipment used should be that having the least damaging effect on ground conditions.

Extreme care should be taken during the planning, design, and placement of a fill to ensure that structural failure does not occur during the project life to allow the material to enter a water body or adjacent wetland. Adequate criteria should establish the factors of safety to be used in the design and placement. Adequate and continuing processes will be necessary to assure that conditions are maintained.

Ensuring Containment of Potential Pollutants Within The Discharged Mass of Dredged or Fill Materials

At times, dredged or fill materials placed, or discharged, into streams, lakes, wetlands, or other water bodies may contain natural materials such as iron sulfide (pyrite), calcium sulfate (gypsum), and various salts. These materials are not pollutants in their source areas but can become pollutants when transported into and deposited in another environment. If polluted materials can be effectively contained by effective BMP's and prevented from affecting water quality, their discharge should not be precluded only because of their quality. Effective containment within the mass of materials is essential for use. It can be done by:

1. Surrounding the poor quality material during placement with walls and blankets of relatively impervious materials such as compacted fill, concrete, or similar materials. Drain blankets for pumpout of fluid may be desirable.
2. Restricting the use of poor quality materials to areas above high-water elevations and capping them with relatively impervious blankets of fill to prevent infiltration of rainfall and subsequent leaching.
3. Blending poor quality materials, such as pyrite, with naturally-occurring neutralizing materials such as crushed limestone during placement.

Protecting Habitat and Providing For Fish and Wildlife Propagation

The disposal of dredged or fill materials into water bodies or wetlands can cause detrimental changes to occur in the habitat for fish and wildlife, particularly in the immediate locality of the discharge. Migration routes or access to select food sources can be blocked or restricted, fish spawning areas destroyed or propagation activities interfered with, and key ecological relationships and interdependencies disturbed.

Best Management Practices for mitigating, or preventing, these environmental problems can involve scheduling of operations to avoid creating problems during conditions that are critical for aquatic and other wildlife. This could include spawning, migration, nesting, and other periods where the effects of discharge activities could be much more critical than during other times. Other practices may involve the proper management of activities as well as the modification or construction of structures and techniques to offset terrain changes, water level and flow alterations, and ravision in the natural physical or biologic integrity of the water bodies and wetlands due to the discharge. They could include:

1. Creating avenues for movement of aquatic life and wildlife through structures formed of dredged or fill materials.
2. Providing protective devices for wildlife encountering or crossing structures formed of dredged or fill materials.
3. Creating necessary habitat improvement measures.

Enchancement or Replacement, Relocation, or Reconstruction of Existing Environment

If, after evaluating all alternatives, the placement of dredged or fill materials into wetlands or other water bodies is justified, and other available Best Management Practices will not effectively prevent adverse effects, enhancement or replacement of the existing environment may be feasible. This must receive consideration if a significant percentage of the water body becomes dry land due to the discharge and/or placement of materials.Practices may include:

1. Creating and maintaining additional wetlands equivalent in productivity to those destroyed by the discharged deposits.
2. Providing shallow or deep water areas equivalent to those destroyed by the placement of materials for the maintenance of aquatic life and other wildlife.

3. Providing for the relocation or replacement of streams that have been designed and constructed to function under original gradient, hydraulic, and aquatic habitat conditions.

CHAPTER 1

MINIMIZING THE IMPAIRMENT OF WATER FLOW OR CIRCULATION

Best Management Practices to reduce, or prevent, the adverse impairment of flow or circulation of waters can involve properly locating, shaping, and orienting masses of dredged or fill materials to minimize flow disruption; limiting their unbroken extent or providing continuous open channels through them; preventing abrupt changes in the elevation of the bottom of stream channels which restrict free movement of aquatic life; and ensuring that the transmission capacity of surface or ground water systems is not adversely affected. If the use of the water body is changed, flow or circulation impaired, or the reached reduced, a permit may be required under the Section 4o4 program.

The discharge, or placement, of a mass of dredged or fill materials into a water body or its adjacent wetlands will alter the elevation of the bottom surface (substrate) of the water or the surface of the wetland. It will reduce the cross-sectional area through which surface or ground water moves and cause subsequent changes in their flow and circulation patterns. Local or areawide changes in water levels, normal fluctuations, velocities, direction of movement, and other characteristics will occur perhaps within the affected body and both upstream and downstream. The degree of the impairment of flow or circulation will depend upon the volume and characteristics of materials discharged or emplaced and the reduction in cross-section resulting.

Adverse effects caused by the alteration of flow or circulation patterns may involve changes in the occurrence, movement, and natural productive capacity of aquatic life; chemical and physical characteristics of the water; and energy capacity for moving sediment and other materials through the natural water system.

Properly Locating, Orienting, and Shaping Masses of Dredged or Fill Materials

The material presented in this and the following section of the guidance is not intended as a justification for, or to condone, the placement of dredged or fill materials into shallow waters or wetland areas. These practices have been done in the past and have caused severe environmental problems. They probably will be done in the future only after full consideration of site conditions,alternatives available, need for the project, and applicable Best Management Practices to ensure that expected adverse environmental impacts will be reduced to acceptable ranges.

Dredged materials discharged for disposal and large fills placed in shallow water or wetlands for engineering purposes can have a major effect on the flow and circulation patterns of water both locally and areawide. These effects can be reduced to a large extent by locating, orienting, and shaping the masses of materials so that they minimize the disruption of flow and circulation. The potential for erosion and the subsequent sediment losses will be minimized also by these practices.

Factors to be considered in designing the most advantageous shape, orientation, or location include the topography of the surface upon which the material is to be discharged or placed, direction of prevailing current or wave movement, irregularity of the contact between land surface and water body, characteristics of the drainage through or around the filled area, and the need to minimize the length of containment dikes. These dikes must be constructed for containment before any discharge of materials takes place. Fills for engineering purposes may consist entirely of materials derived from underwater sources or of these materials capped by a layer of stronger more competent fill obtained from land sources.

Areas of indentation in shorelines of water bodies can be considered for the location of deposits of dredged or fill materials. If they are sensitive wetlands they should be avoided, if at all possible. The proper design and discharge of these deposits, however, could result in the creation of a wetland habitat to enhance the environment as well as minimizing impairment of flow and circulation.

If indentations are located in the straighter portions of stream channels and on the inside of stream bends, properly shaped masses of dredged or fill materials situated in them will be outside of the main currents and have a minimal effect on their flow. In lakes or other open water bodies such deposits will have only a minor effect on currents which move along the shore. Figure 1-1 illustrates how dredged materials can be placed with rip-rapped containment dikes in indentations of a stream. In properly located areas, the lineal extent of dikes can be minimized, particularly if the landward side has sufficient topographic relief to contain the materials.

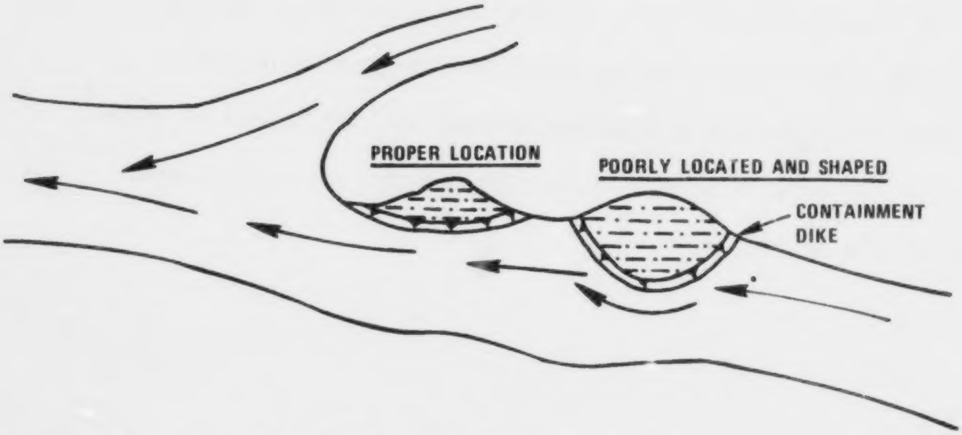


Figure No. 1-1 - Deposits of Dredged Materials Contained by Dikes Can Be Located So They Do Not Project Into Main Currents

If the areas of indentation are the result of overland erosion rather than stream meanders, or wave action in open bodies of water, they represent areas where surface drainage will concentrate. In this case, measures must be devised to provide for diverting the drainage around the contained dredged or fill materials or passing it through or beneath them. Diversions should be designed to prevent subsequent erosion by concentrated flow and to simulate natural features. Passing surface water through the deposit will require a spillway over the containment dike that will not allow erosion or cause failure of the structure and release of the contained materials. If culverts, or other structures, are to be used to pass flows through or beneath the deposit, they will have to be considered during the design stages and placed when constructing the dikes and before discharge begins behind them.

Dredged materials can be used to create marshy islands and perhaps shallow wetlands in areas where deeper water existed before. These deposits, if placed in open waters, must be shaped to provide the least feasible cross-sectional area to be exposed to the natural flow of water. Figure No. 1-2 illustrates desirable shaping and orientation for such placements. They can be contained by dikes of some type or another. Rip-rap or some other erosion-protecting devices will be needed as either current or wave action will tend to remove an obstruction in the water and deposit it into another area.

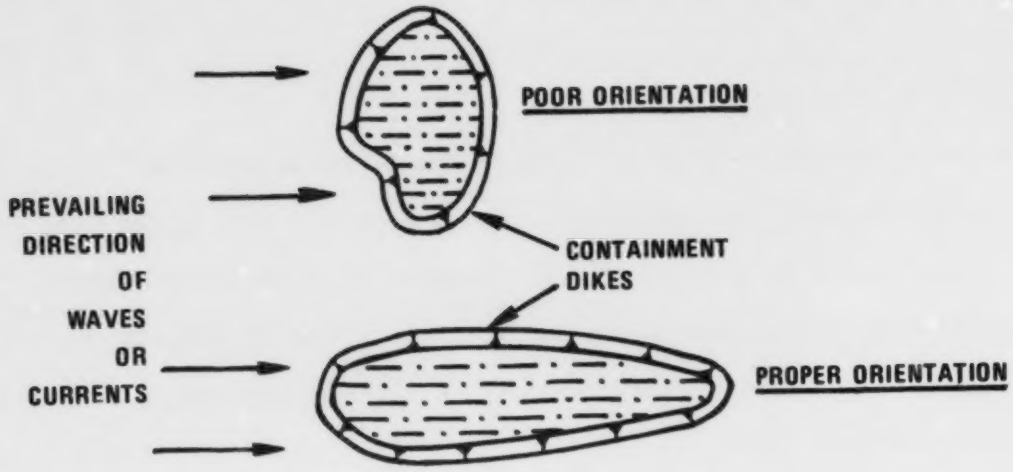


Figure No. 1-2 - Properly-Oriented Deposit of Dredged Materials Should Have Long Dimension Parallel To Prevailing Movement of Waves or Currents (After Reference No. 18).

Providing Flow Through Dredged or Fill Materials

Dredged or fill materials should not be discharged or placed into water bodies or wetlands over such extensive areas or alignments that they adversely disrupt the normal flow or circulation of either surface or ground waters. Extensive areal deposits may include those used for disposing of quantities of dredged or fill materials through the development of sites for port facilities, power generating stations, and similar projects. Extensive lineal deposits include causeways and roads, canals, and similar structures.Materials placed into these deposits may consist of sediments dredged from water bodies and earth or rock fill obtained from land sources.

Permits for discharge of these materials may be required under Section 404 if changes in the use of areas of navigable waters are involved, flow or circulation impaired, or reaches reduced.In these cases, implementation of BMP's will be conducted in accordance with requirements of the 404 program.

Deposits of Large Areal Extent

Large masses of materials can be located, shaped, and oriented to minimize changes in water flow and circulation patterns. If this is not adequate, practices can be utilized to allow movement of water through these dredged and fill deposits. Open channels, culverts, systems of channels and culverts, pervious rockfill surface and subsurface sections, and alternating sections of each should be considered for application, either singly or in combination.

The occurrence, nature, movement, and extent of both ground and surface waters must be considered in the design of Best Management Practices to minimize detrimental flow and circulation changes. In general, the direction of ground water flow is similar to that of surface water but anomalies do occur. They must be considered to prevent the occurrence of flow and circulation problems at later dates.

Figure 1-3 is a sketch of a fill for a small power plant incorporating open channels through which water can flow and minimize disruption due to this facility. Bridges can be used for channel crossings but culvert installation also may be practical.

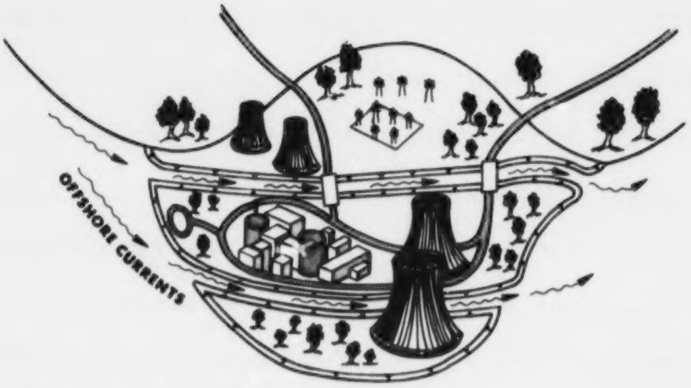


Figure 1-3 - Fill For Small Power Plant With Open Channels Provided For Water Movement. Retaining Dikes and Channel Banks Should Be Protected With Rip-Rap

Deposits of Large Linear Extent

Fills that are installed to provide for such linear structures as causeways for highways or railroads, levees, and similar facilities often extend across the natural drainage of streams or wetlands. Bridges or culverts usually are installed where stream channels occur. Ground water and surface flows may have to move laterally through or over natural linear features to reach these structures. As a result, more extensive and drastic differential water surface elevations can occur to initiate movement of water through the few open structures. Depth changes, erosion and sediment deposition, and other environmental problems may result.

Wetlands often consist of soft, compressible deposits of fine-grained silts and clays, loose sands, and organic matter. The weight of a causeway fill can cause these materials to consolidate and/or move laterally to make way for and support the fill (See Figure No. 1-4). If the fill

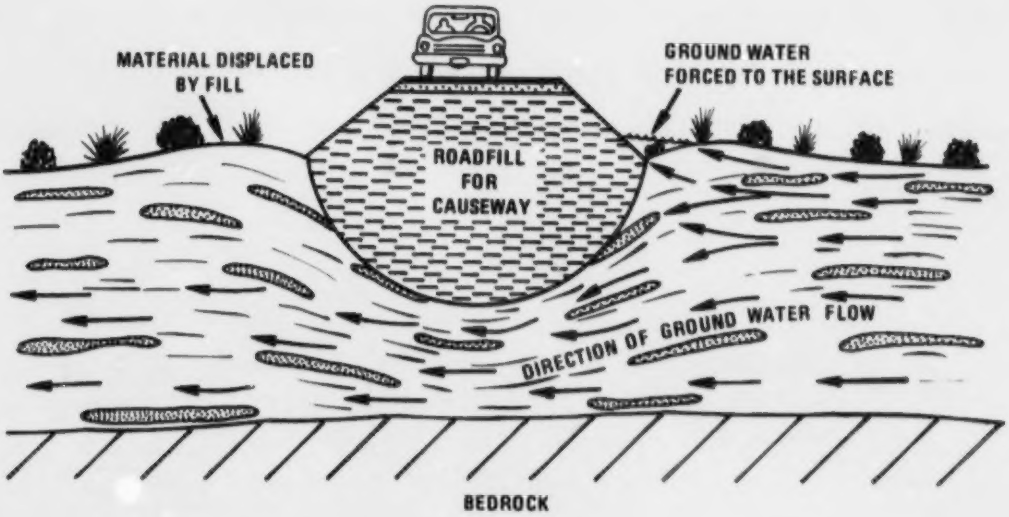

MATERIAL DISPLACED BY FILL
GROUND WATER FORCED TO THE SURFACE
ROADFILL FOR CAUSEWAY
DIRECTION OF GROUND WATER FLOW
BEDROCK

Figure No. 1-4 - Impervious Roadfill Section Placed On Wetland Consisting Of Soft Organic Sediments With Sand Lenses. The Natural Material Consolidates and Restricts Ground Water Flow materials used are relatively impervious compared to the natural deposits, the cross-sectional area through which the ground water moves will become reduced, and the flow restricted. Ground water levels on the up-gradient side of the fill will rise and force water to the surface. On the down-gradient side, water levels will be lowered. These water level changes can cause severe environmental problems on either side of the causeway.

Best Management Practices for preventing, or minimizing detrimental changes in both surface and ground water flow and circulation patterns can include such measures as using pervious fill materials and alternating sections of pervious and impervious fill and open channel sections. (See Figure Nos. 1-5 through 1-8). Perviousness, or permeability, is a function of the characteristics of the material. Sand, sand and gravel, or similar materials allow movement of water through them and may be used to provide a pervious fill section. The BMP's should function to prevent restriction of surface and ground water flow and circulation. Structures must be constructed to pass low flows without restricting movement of aquatic creatures and other water-dependent wildlife as well as the high discharges from floods.

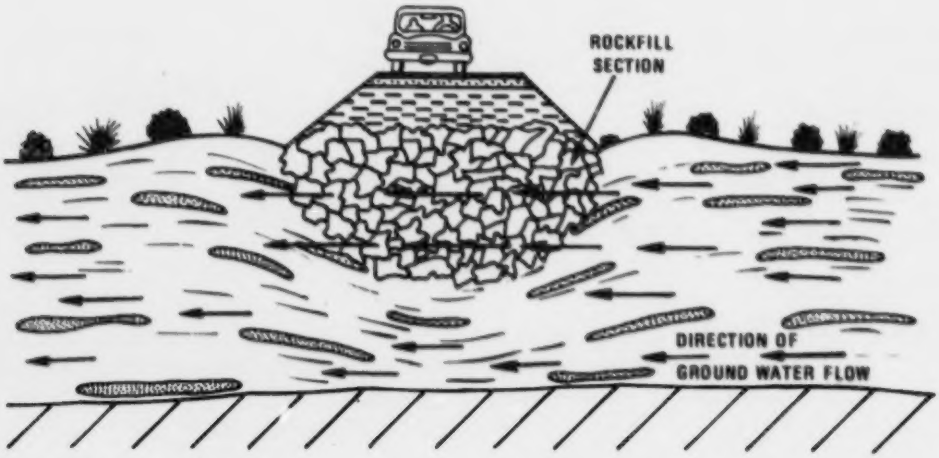


Figure No. 1-5 - Pervious Roadfill Section On Wetland Allows Movement Of Ground Water Through It and Minimizes Flow Changes.

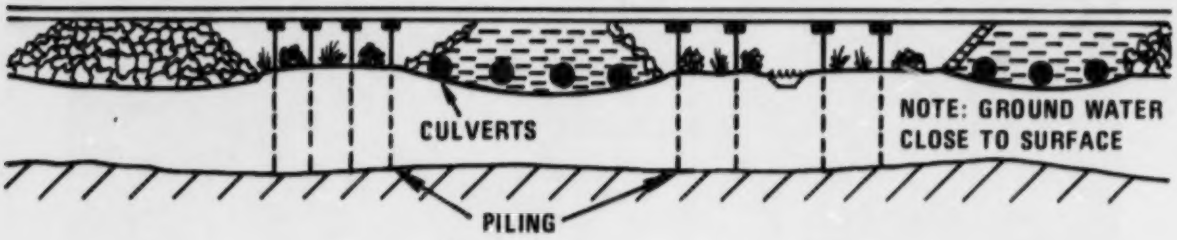


Figure No. 1-6 - Causeway Across Wetland Designed To Minimize Disruption of Surface and Ground Water Circulation. Fills Composed of Pervious Rock or Impervious Earth Materials.

Fills For Stream Crossings

Any fill, or other structure, placed into a stream channel through which water moves will restrict the cross-sectional area through which the flow passes and, to some extent, obstruct the flow or cause changes in circulation patterns. Best Management Practices include techniques for minimizing the obstruction of flow and circulation changes. For example, a bridge that spans the entire stream does not constrict the channel if it places no obstruction in it. (See Photo No. 1-1). If piers in the channel are used, they should be located and spaced to minimize the flow obstruction and disturbance. (See Figure Nos. 1-7 and 1-8). During flood flows in forested areas, fallen timber may be carried downstream to obstruct flows when they are trapped across bridge piers. When designing a bridge, consideration must be made of the probable length of trees or logs expected during floods. The distance between piers should exceed this length, otherwise obstruction of flow, flooding, excessive erosion, or bridge failure may result to cause damage to local aquatic habitat as well as downstream flood-prone areas. If this is not feasible, arrangements should be made to quickly remove blockages during flood flows.

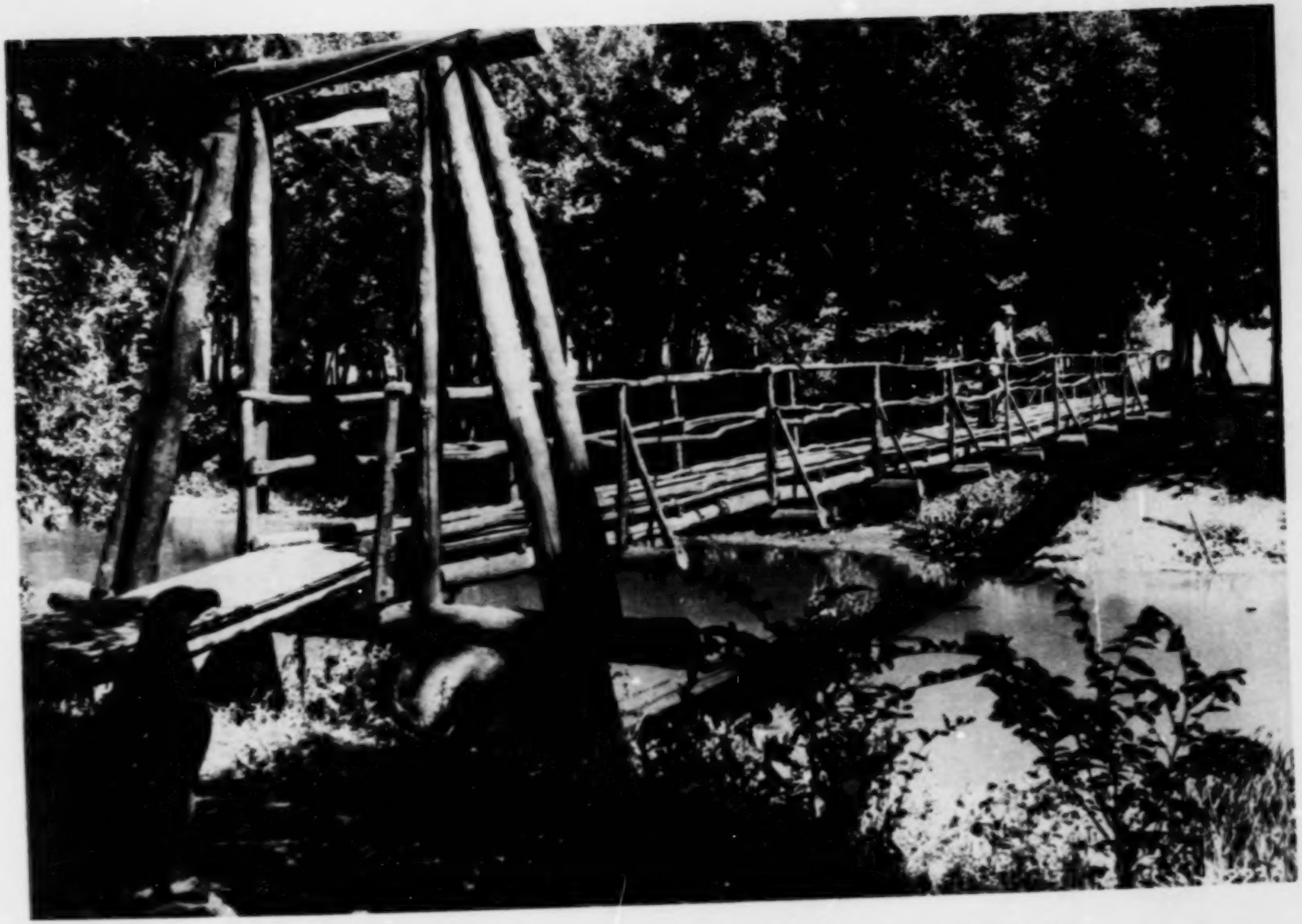


Photo No. 1-1 - Small Wooden Suspension Bridge Spanning Stream (U.S. Forest Service).

Freeboard allowance (the distance between the design stormwater surface and the bottom of the bridge deck) should always be designed to reduce the potential for debris blockage (Compare Figure No's. 1-7 and 1-8). The superstructure, especially the guardrails, should be constructed to maximize debris passage.

Culverts should be designed, constructed, and maintained so that they not only pass high flows without creating environmental problems, but also the low flows. During low flows, passage for aquatic life may be restricted. Species of fish occurring in the stream involved must receive consideration. If possible, the existing stream bed should be completely spanned by a half-round culvert. (See Photo No. 1-2).

BETTER ENVIRONMENTAL DESIGN

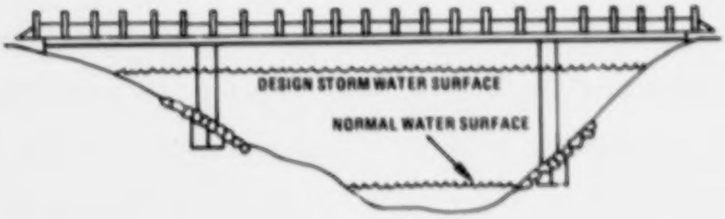


Figure No. 1-7 - Stream Crossing With No Construction Required In The Normal Channel.

POORER ENVIRONMENTAL DESIGN

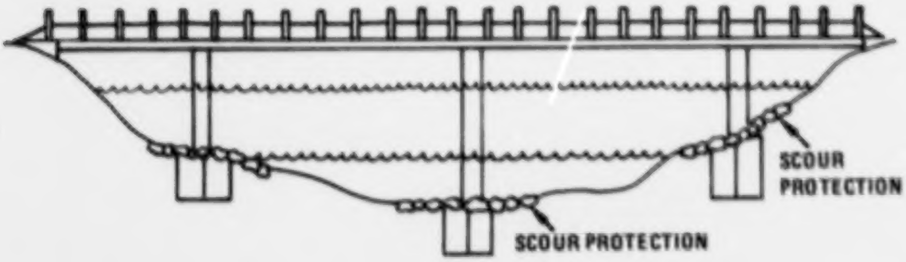


Figure No. 1-8 - Stream Crossing With Pier In Central Section Of Normal Channel.

Photo No. 1-2 - View Through Large Half-round Culvert. Note Natural-appearing Stream Channel For Fish. (Reference No. 28).

If a round culvert is used, it should be installed sufficiently below the stream channel to have the water level well up into the lower section of the structure to allow fish passage and still retain its capacity for passing flood flows. After a period of time, gravel or other sediments will deposit in its bottom and create a naturally-appearing channel (See Figure No. 1-9). An example of a culvert installed at too shallow a depth to allow passage of fish during low flows is shown in Photo No. 1-3.

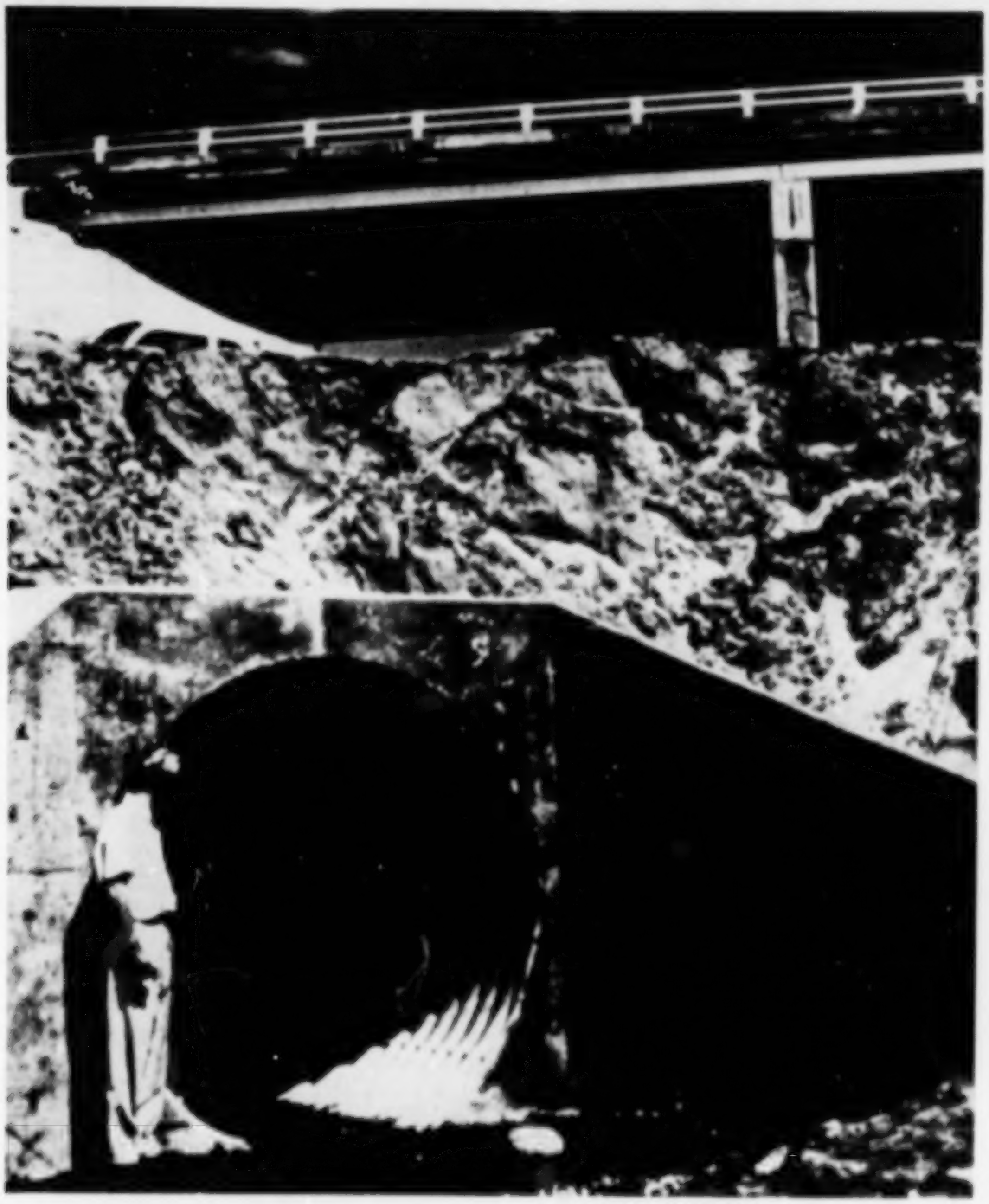


Photo No. 1-3 - Large Culvert Installed With Little Consideration For Adequate Depth of Flow For Fish Passage (U.S. Forest Service).

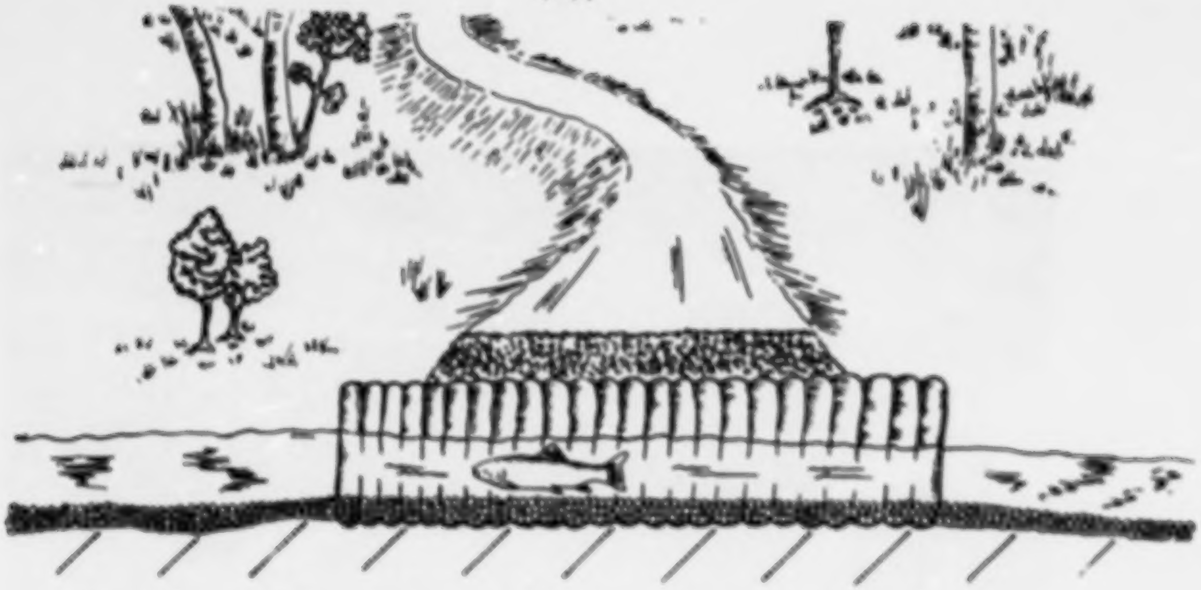


Figure No. 1-9 - Round Corrugated Culvert Placed Below Streambed To Provide Fish Passage During Low Flows (Adapted After Reference No. 10).

Culverts should also be installed with their inverts (bottoms) on the same gradient as the streambed. Steeper gradients may create velocities too great for aquatic life, and gradients that are too low will create ponding upstream and probably have a limited capacity to pass the designed flows (See Figure No. 1-10).

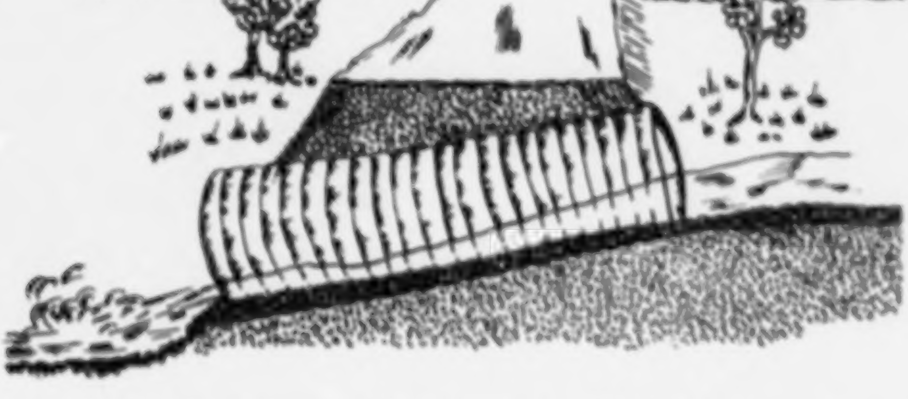


Figure No. 1-10 - Round Corrugated Culvert Placed At A Gradient Steeper Than Stream Gradient. High Velocities Result (Adapted After Reference No. 10).

Many BMPs can be used to enhance the flow characteristics through culverts to provide better conditions for fish passage. For many of the detrimental flow problems created by improper culvert installation there are remedial structures, or measures, that can be utilized to minimize them. Several are illustrated in the following illustrations (Figure No. 1-11 and Photo Nos. 1-4 and 1-5). Best Management Practices for culverts which provide for passage of fish and aquatic life should include a consideration of routine maintenance to keep them clear of debris and sediment. In the absence of maintenance, the fish passage design feature can be negated.

The capacity of culverts to pass flood flows should always be maintained. This must be considered during the design and placement of culvert structures.

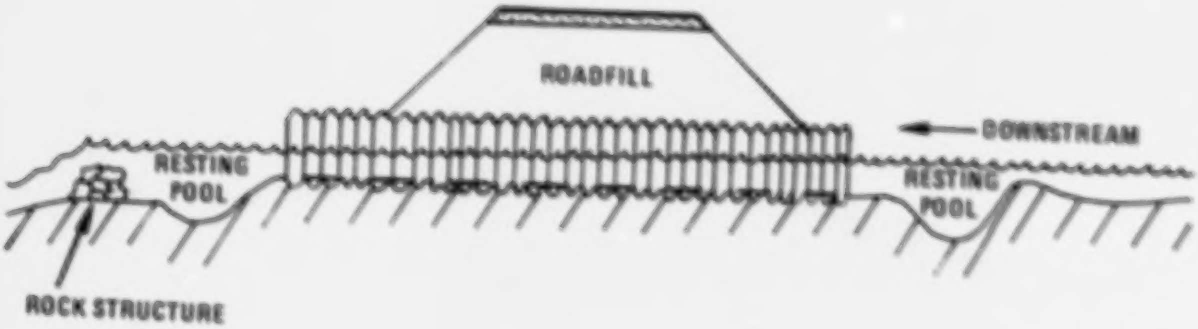


Figure No. 1-11 - Rock Barrier Structure At Discharge End of Culvert Providing Adequate Depth of Water For Fish Travel. Resting Pools Help Fish Conserve Energy.

Photo No. 1-4 - Gabion Structure Being Installed To Provide Adequate Depth of Flow Through Culvert. For Detail See Figure No. 1-11 (U.S. Forest Service).

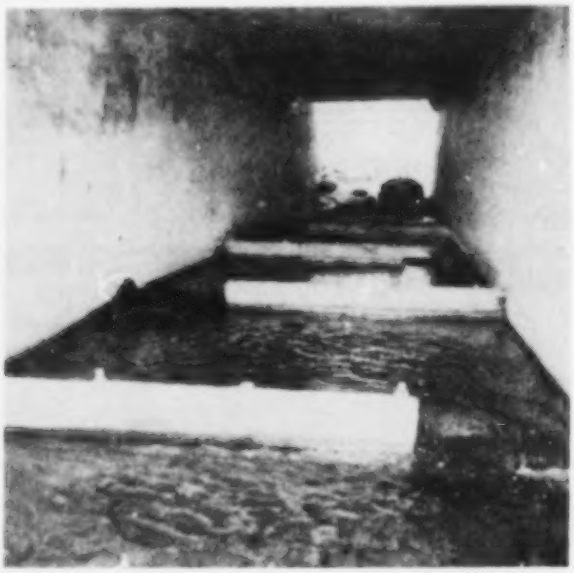


Photo No. 1-5 - Reinforced Concrete Box Culvert With Baffles To Provide Adequate Flow For Fish Migration. (Reference No. 28). Note Gravel In Bottom of Culvert.

Multiple culverts can be installed through a fill of greater linear extent in wetlands to prevent concentration and restriction of flow. (See Photo No. 1-6). One or two large culverts through the center of the fill could transmit as much water as the many smaller ones but would require much more lateral flow changes and concentrations of discharge. One or more of the smaller multiple culverts can be placed at lower elevations than the others to provide adequate flow for passage of fish and other aquatic life during low flows.

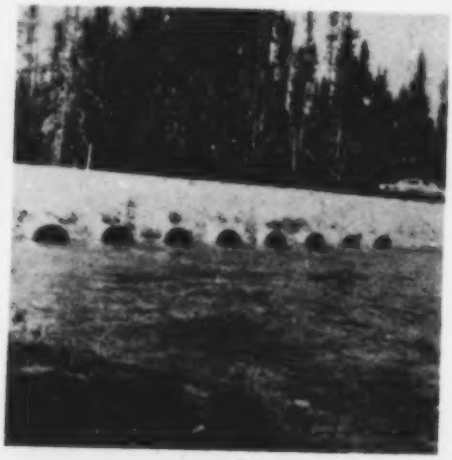


Photo No. 1-6 - Multiple Culverts Provide More Uniform Passage of Streamflow and Prevent Concentration of Flow (Reference No. 28).

Another type of structure which minimizes stream flow restriction is shown in Photo No. 1-7. It consists of a concrete low-water bridge which permits free flow of water under it during low water. High flows will overtop the structure.

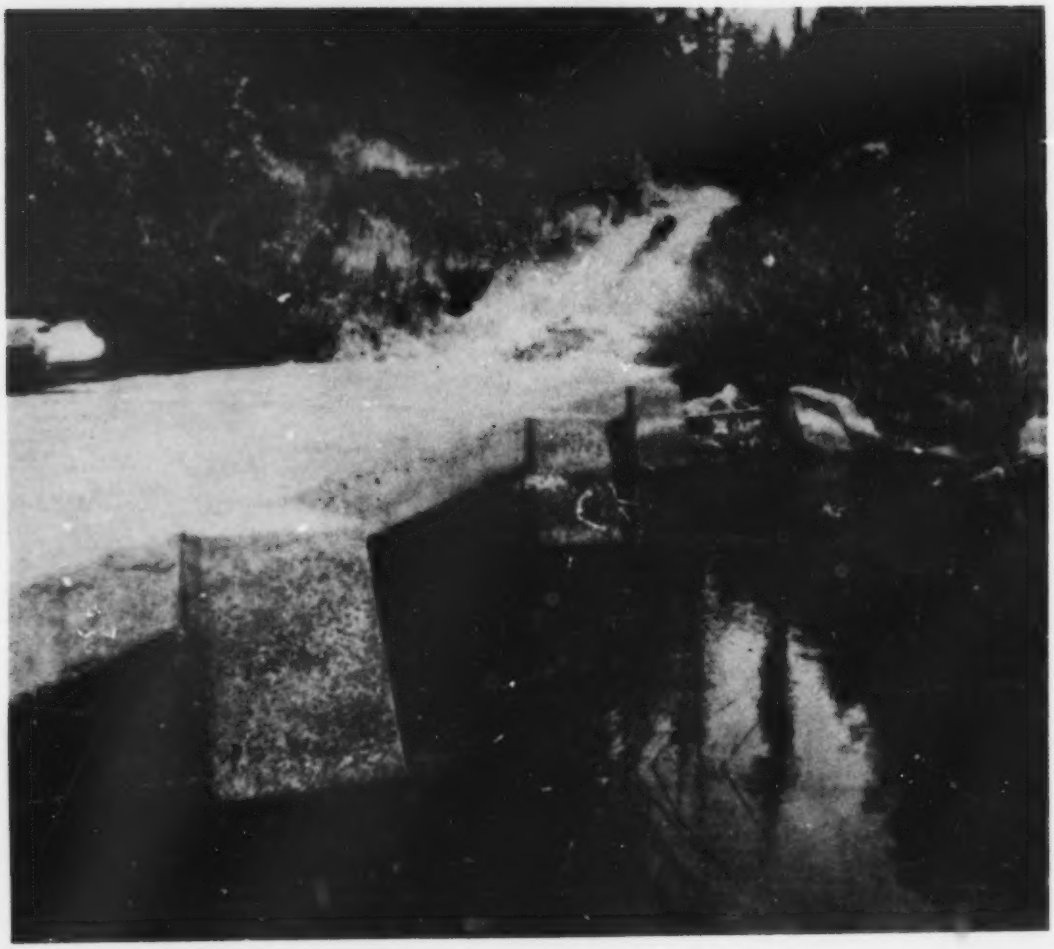


Photo No. 1-7 - Example of Low Water Bridge That Does Not Restrict Low Flows and Allows Free Passage of Aquatic Life (Reference No. 28).

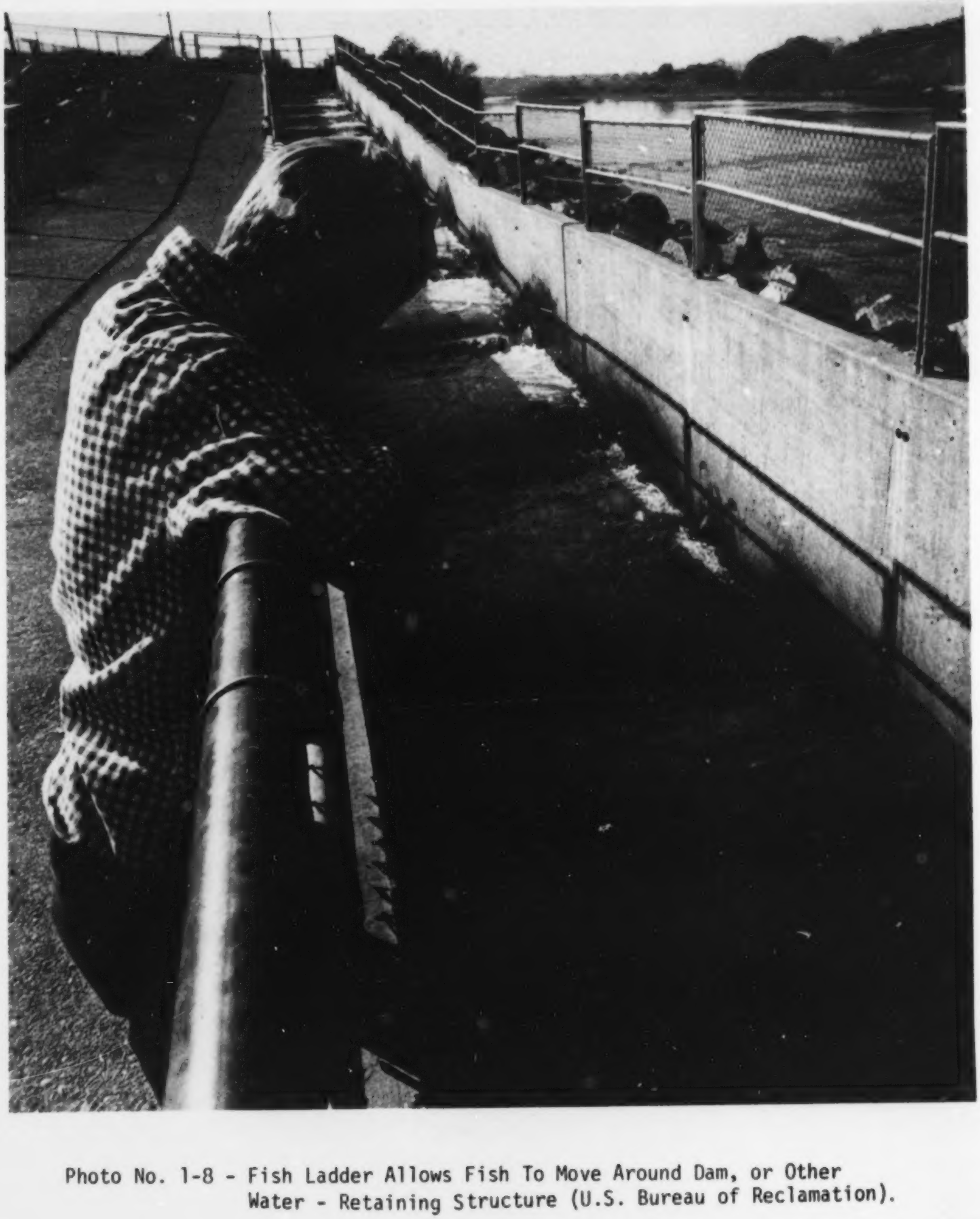


Photo No. 1-8 - Fish Ladder Allows Fish To Move Around Dam, or Other Water - Retaining Structure (U.S. Bureau of Reclamation).

Preventing Detrimental Elevation Changes In Channels

Some stream-crossing structures such as culverts and bridges may create abrupt stream-channel and water surface elevation changes that can have detrimental effects on the movement of aquatic life and possibly cause other environmental problems such as erosion and sediment losses.

Figure No. 1-12 illustrates four different problems that anadromous fish can encounter as a result of culverts being installed above streambed elevations. All of these problems can be resolved by lowering the culvert to reduce the elevation change, decreasing the culvert gradient, increasing the depth of water in the culvert bottom, or providing for resting pools at either end. To provide adequate design at a minimal cost, information must be obtained regarding the jumping ability of the fish involved and their speed and endurance.

Structural aids to provide increased water depths and other advantages are shown in Figure No. 1-11 on Page 1-15. They provide the required

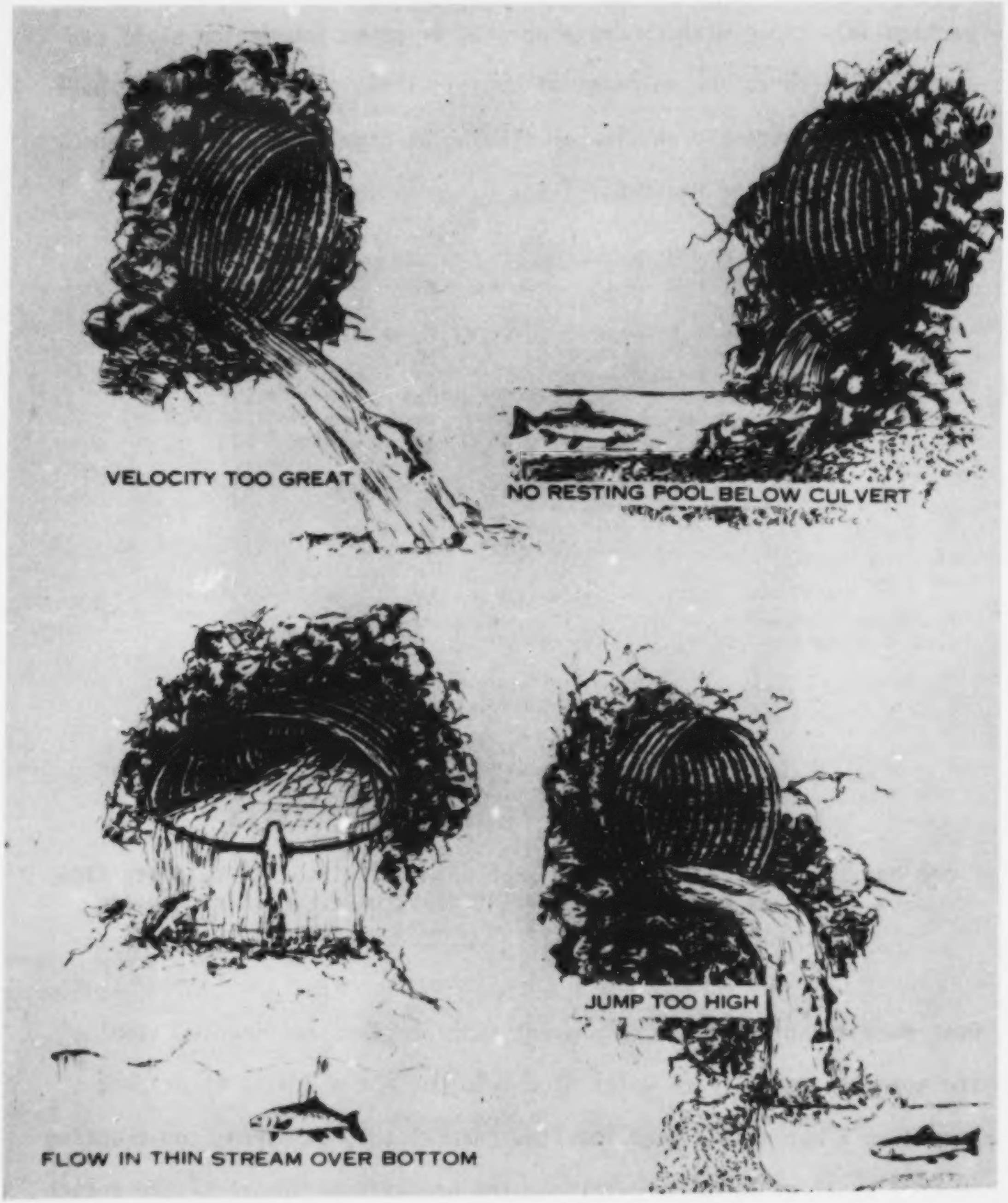

VELOCITY TOO GREAT
NO RESTING POOL BELOW CULVERT
JUMP TOO HIGH
FLOW IN THIN STREAM OVER BOTTOM

Figure 1-12 - Culvert Installations Which Restrict Fish Passage (Reference No. 10).

resting areas and depth of water for passage. Some types of bridges, particularly those with concrete aprons, or other foundation slabs can act as barriers to the movement of aquatic life. If water flowing over the apron is extremely shallow or flowing at high velocity, fish cannot move through it (See Photo No. 1-9).

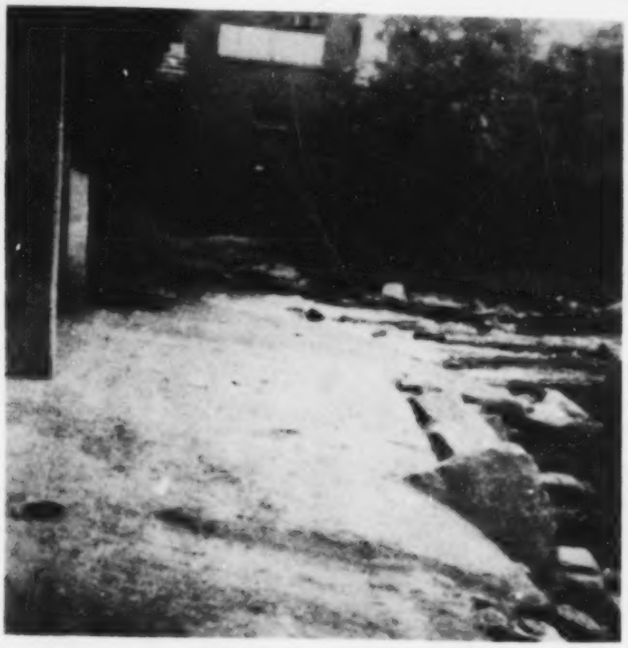


Photo No. 1-9 - Bridge Foundation Slab Showing Thin, High-Velocity Flow of Water and the Extent of Jump Required for Passage (Reference No. 28).

Best Management Practices to prevent such problems can involve sloping the apron to concentrate water flow into one end and make it deeper; providing a narrow and deep low-flow channel through apron; constructing several small pools downstream from the drop-off to progressively reduce abrupt elevation change; and placing rock obstruction in the channel to minimize velocities of flow.

CHAPTER 2

PREVENTING, OR CONTROLLING THE RUNOFF OF EXCESS SEDIMENT LOADS OR TURBIDITY INCREASES

Loss of sedimentary materials by erosion and transport processes can occur during the placement, or discharge, of dredged and fill materials or after the mass of materials is actually in position. Best Management Practices to prevent or minimize this problem must receive full consideration during the entire process from planning prior to placement, through the implementation or installation period, and until the materials are stabilized and protected adequately or removed. If possible, discharge of materials should take place in areas of containment or on dry land. This can be done by scheduling the discharge during low flows, temporarily diverting, or by-passing the stream, or excluding waters from sites through the use of some type of retaining structures such as cofferdams, caissons, and embankments. Following placement, the mass of dredged or fill materials must be protected from erosion by rainfall; sheet runoff; and concentrated streamflow, wave action, and water currents. Surface protection measures should be designed and constructed to extend above projected design flood elevation and prevent underlying materials from being eroded and transported into downstream areas.

Examples of Best Management Practices to prevent or restrict the runoff of excess sediment loads and increased turbidity are presented in this chapter, along with discussions regarding some factors to consider in their application.

During Discharge or Placement of Materials

Most dredged and fill materials consist of relatively fine-grained sediments that moving water can erode and transport downstream during discharge or placement. Because of this, all possible efforts should be exerted to discharge dredged materials into contained areas and to place fill materials on foundations that are not submerged at the time of placement.

Dredged Materials

Disposal of dredged materials must be done in areas of containment so that runoff of the materials is prevented. Containment generally can be achieved through the use of dikes, or embankments, made from materials obtained in the vicinity. If disposal is in a lowland, a dike may be required to surround the area completely. In an upland, however, a dike may be needed only across the lower boundary of the area to provide storage (See Figure 2-1). The stability of the dikes must always be considered in the design to ensure that failure does not occur to release the contained material back into the water.

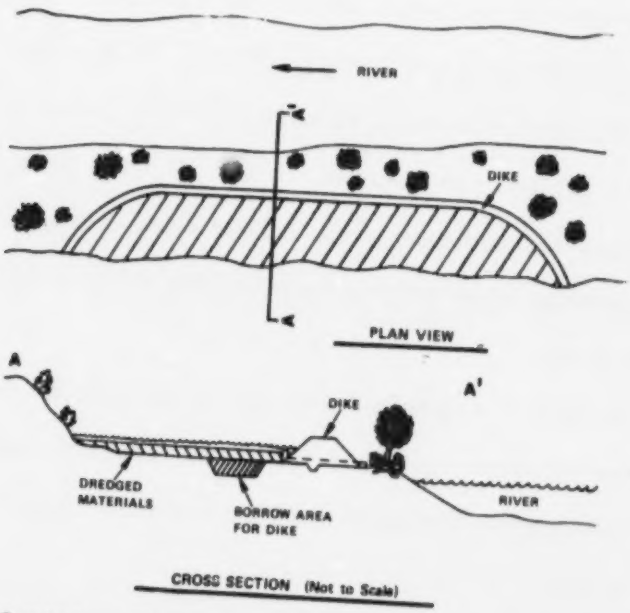


Figure No. 2-1 - Containment For Dredged Material In Upland Area Adjacent To River.

Dredged materials generally consist of a slurry made up of water and solid sedimentary materials. After being discharged into the disposal area, the coarser particles settle out; and the water, containing fine-grained sediment particles (silts and clays), becomes effluent when it leaves the containment site. Control of this effluent poses a major solid-liquid separation problem if the containment has a limited storage capacity, much of the material is fine-grained, and periodic removal of the effluent is necessary.

If the dredged materials consist principally of sand, or coarser materials, the detention time in the containment may be sufficient to remove most of the sediments. In this case, an outlet pipe with the intake high in the water column will provide for removal of the relatively clear effluent (See Figure No. 2-2). An energy dissipator or level spreader should be provided below the discharge to prevent erosion and provide additional settling and filtering capacity.

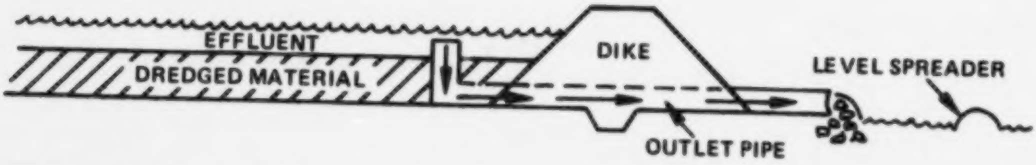


Figure No. 2-2 - Outlet Pipe For Draining Clear Effluent From Containment .

Fine-grained sedimentary materials such as silts and clays stay in suspension for longer periods of time than coarser materials and need additional efforts to make them settle out. Certain chemicals added to dredged materials as they enter a containment area can cause these materials to flocculate (aggregate into small lumps) and settle out. Lime has been used as well as organic polymers. Effective use of flocculants requires that a knowledge of the fine-grained sediment particle's reaction to each flocculant be obtained. In addition, a separate partition in the containment area may be required to provide an area for the flocculated material to settle out.

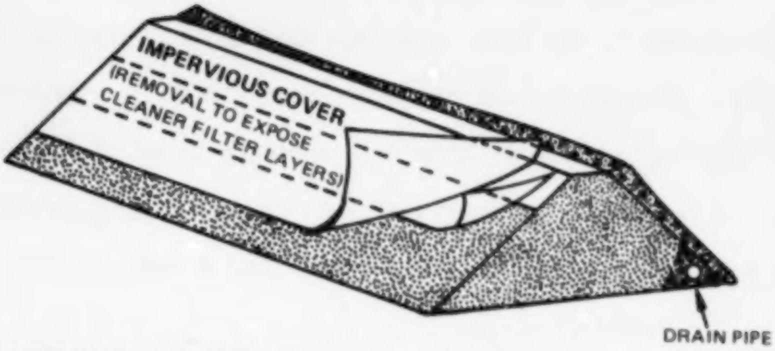
If fine-grained materials are still present in the effluent to leave the containment, filtration through pervious sand or sand and gravel sections in the dike, sandfilled weirs, filter cloth screens, and similar structures should be considered (Figure No. 2-3). The quality of effluent discharging from a given filter system will be dependent on the amount of solids entering it and the filtering capacity of the medium through which it moves. Good or effective filtration will achieve removal efficiencies of 90% or more in the intermediate or low ranges of effluent suspended solids (between 1 and 10 grams/liter). Proper engineering judgement is essential to obtain the optimal use of all alternative techniques.

Another alternative to consider is the use of spray irrigating techniques to dispose of the water containing fine-grained materials and prevent its runoff. If this is done properly, the water portion of the mixture will infiltrate soils and leave the sediments on the surface where they can be stabilized by vegetative growth.

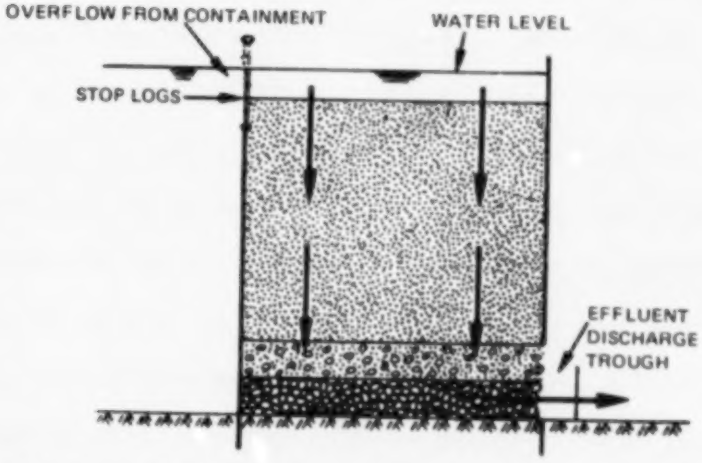
Fill Materials

To prevent the runoff of sediments and their accompanying pollutants, the preparation of foundations for and the placement of fill materials should take place on land that is not submerged, if at all possible. If the fill materials consists only of large, consolidated rock fragments that are not subject to water movement, placement into a water body may result in no sediment runoff problems.

Disturbance of the ground and movement of mobile land equipment in water bodies where excess sediment losses and runoff can occur should be


IMPERVIOUS COVER
(REMOVAL TO EXPOSE
CLEANER FILTER LAYERS)
DRAIN PIPE

3(a) PERVIOUS DIKE WITH MULTI-LAYERED IMPERVIOUS COVER
(Adapted From Reference No.)


OVERFLOW FROM CONTAINMENT
WATER LEVEL
STOP LOGS
EFFLUENT
DISCHARGE
TROUGH

3(b) DOWNFLOW SANDFILL WEIR (Reference No.)

▨	FILTER MEDIUM	■	COARSE STONE
▨	GRADED GRAVEL	▨	FOUNDATION SOIL

Figure No. 2-3 - Techniques For Filtering Fine-grained Sediments From Effluent (After Reference No. 17).

done only when essential and no other alternative exists. Equipment used should be designed to minimize ground disturbance. Filtering out sediment being transported in the water from the construction site may be accomplished, if practical, through the use of filter-fabric made of polyprohylene monofilament sheeting or similar materials produced by manufacturers for this purpose. If possible, structures such as bridges should be designed so that the need for support piers located in the channel section can be avoided. (See Photo No. 2-1).

If construction activity or placement of fill must take place in the stream or other water area, foundation surfaces that are not submerged (in the dry) can be obtained by temporarily diverting the stream or by using some type of cofferdam, caisson, or other structure to exclude the water. Scheduling the activity during periods of low flow or low water levels also will enable placement of fill to take place in the dry above the water sufaces when the potential for erosion by surface water is minimal.

A technique of temporarily diverting a stream for placement of a culvert and a road fill is shown in Figure No. 2-4 and a completed facility in Photo No. 2-2. A small section of new channel is excavated, or a flume constructed, adjacent to the existing channel. (The channel should be lined with impervious material such as plastic sheeting or some other protection provided to prevent bank or bed erosion and the excavated material protected from erosion.) The stream is diverted, the culvert installed, and the road embankment placed. Then the stream is diverted back into the original channel. The diversion channel is backfilled, and the road fill is completed. Temporary diversion of streamflow may be done for placement of fills ranging from minor embankments for logging roads to major ones for the construction of earth dams (See Photo No. 2-3).

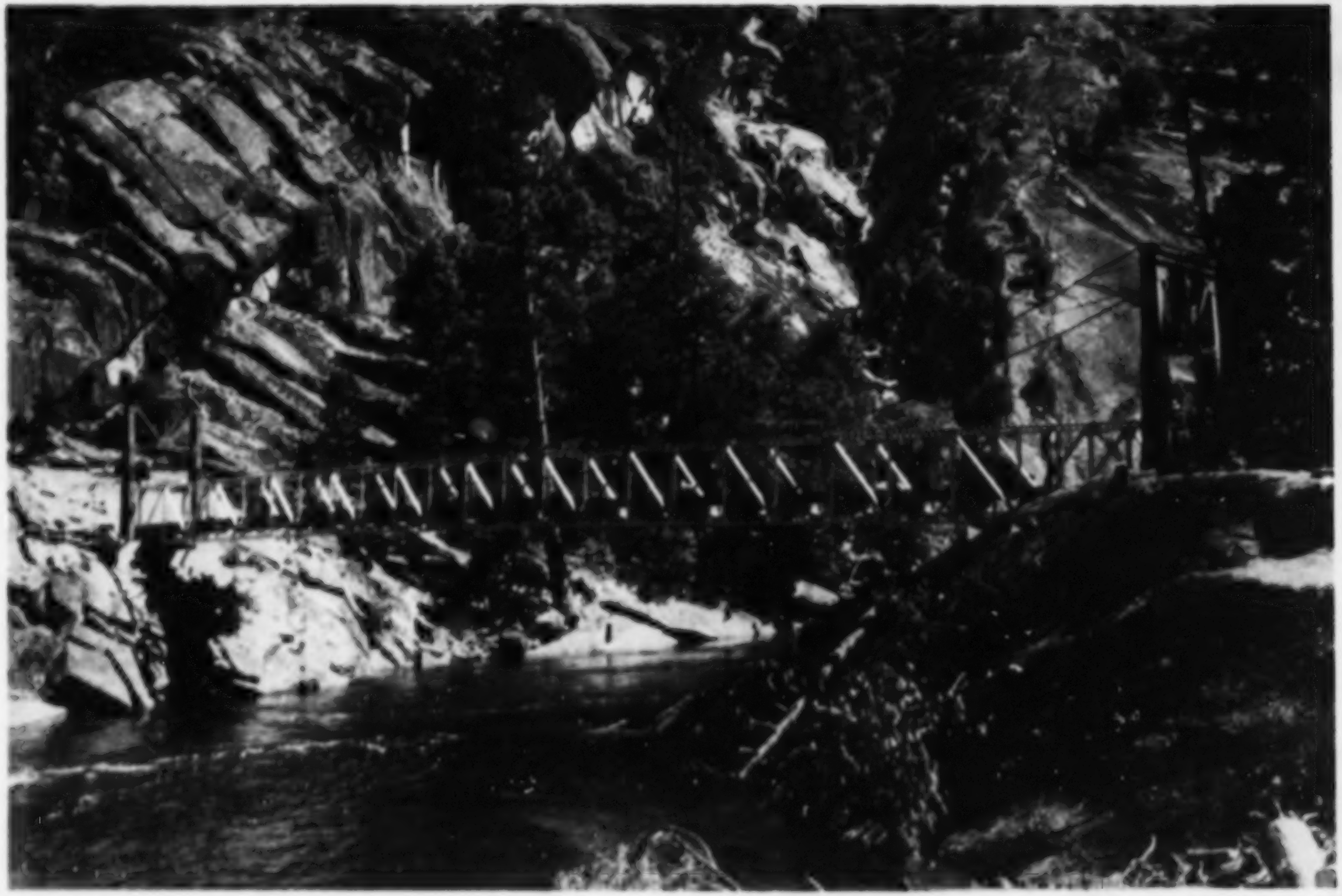
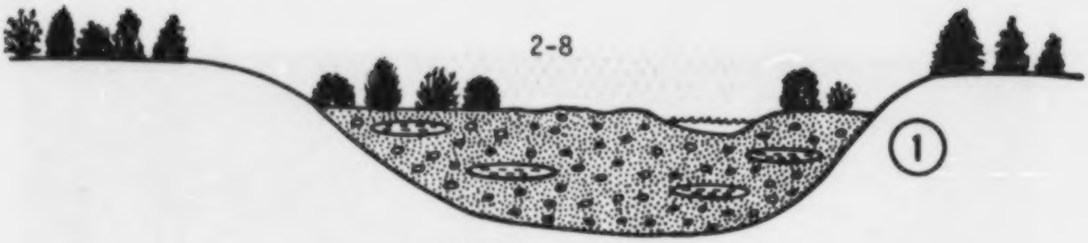
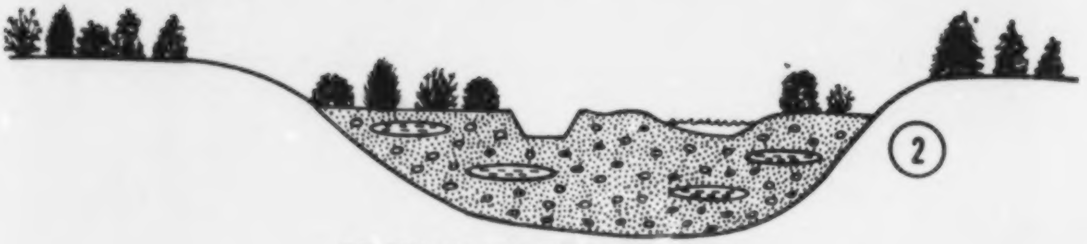


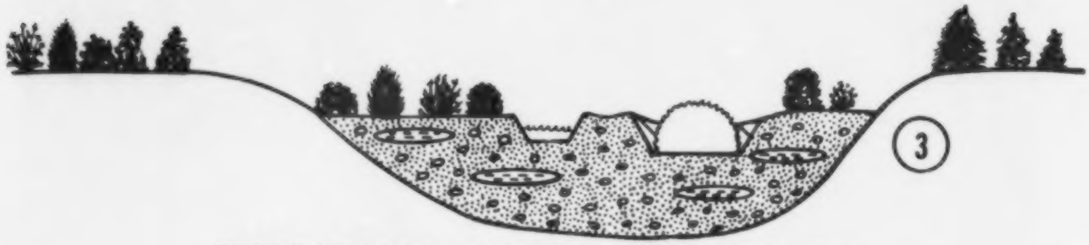
Photo No. 2-1 - Bridge Spanning Stream. No Stream Disturbance Required For Pier Construction In Channel (U.S. Forest Service).



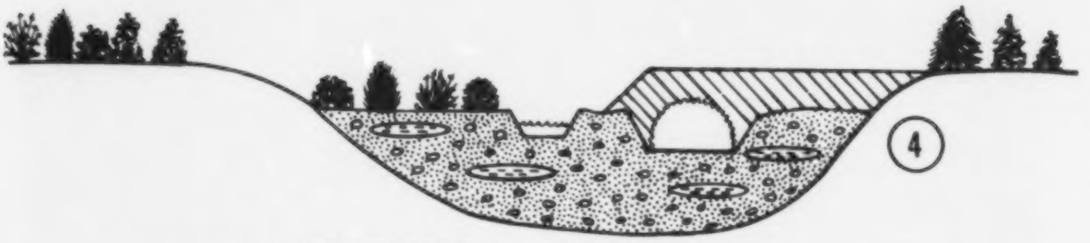
NATURAL STREAM



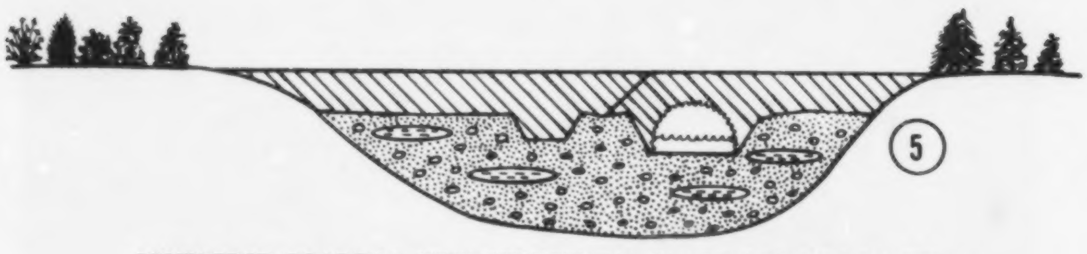
DIVERSION CHANNEL EXCAVATED



STREAM DIVERTED, CULVERT PLACED IN EXCAVATION



EMBANKMENT—FILL PLACED OVER CULVERT



COMPLETED ROADFILL WITH STRUCTURAL PLATE ARCH CULVERTS, STREAM BACK IN ORIGINAL CHANNEL

Figure No. 2-4 - Procedure For Installing Culvert When Excavation In Channel Section of Stream Will Cause Sediment Movement and Turbidity Increases.

Photo No. 2-2 - Example of Completed Culvert That Does Not Restrict Streamflow or Movement of Aquatic Life (U.S. Forest Service).

Cofferdams are temporary structures used to exclude water from or permit dewatering of an area for the construction of fills on foundation surfaces that are not submerged. The type of cofferdam used depends upon the depth of water at the site, characteristics of the foundation materials, geometry of the structure proposed, and expected water-level fluctuations. They can be made of earth embankments, steel or timber sheet piling, and other watertight materials.

Caissons are similar to cofferdams. While cofferdams usually are removed following completion of the construction or fill placement, caissons generally form an integral part of the structure. Caisson means "box" in French. These structures can be rectangular, cylindrical, or in other configurations. They are driven, jacked, or allowed to sink under their own weight into position to exclude the water.

As none of these structures are totally impervious, particularly at contacts with natural materials, they may require pumping out water that seeps in. Proper disposal of the pumped water is essential. It may be e sprayed on land or held temporarily in detention ponds until sediments have have settled out.

Photo No. 2-3 - Flume For Temporary Diversion of Water Through an Earthfill Dam Site. (Reference No. 19).

Cofferdams used to dewater foundations of earthfill or rockfill dams often become portions of the principal structure (Figure No. 2-5). They function as barriers in the river channel immediately upstream from the dam foundation while a diversion tunnel or other structure transmits the water flow back to the channel downstream from the site. The site can be excavated, fill placed, and other activities conducted without being subjected to water flows which can cause sediment runoff and pollution problems.

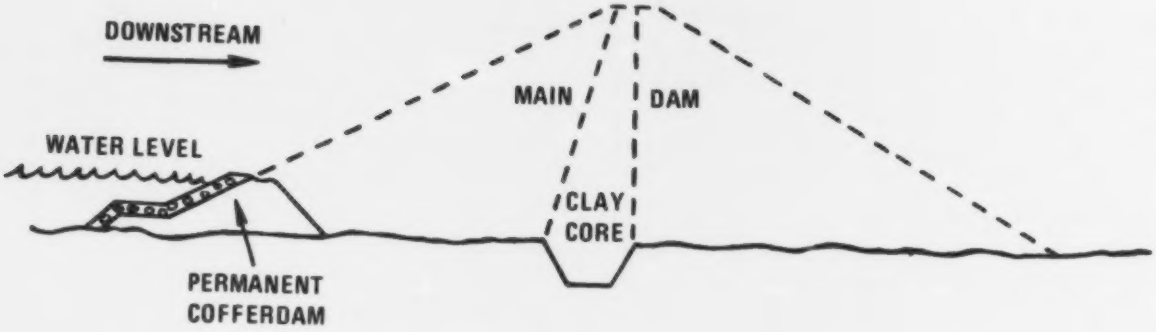
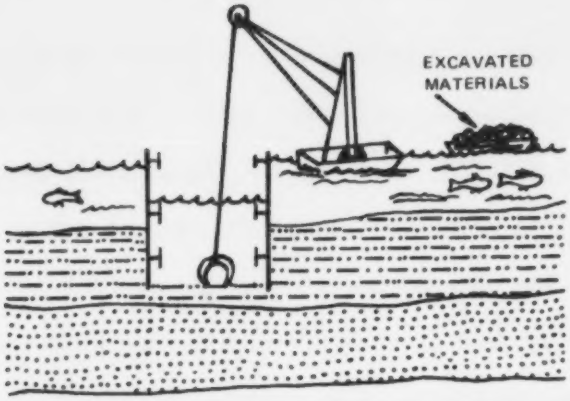
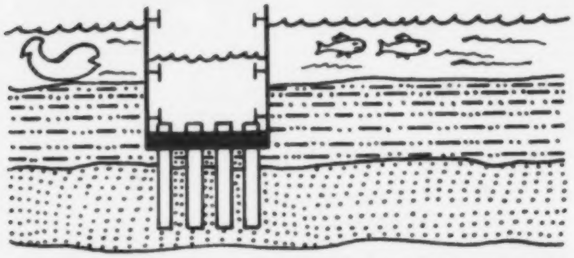


Figure No. 2-5 - Sketch Showing Cofferdam, Which Diverted Water To A Tunnel, To Be Incorporated In Main Structure.

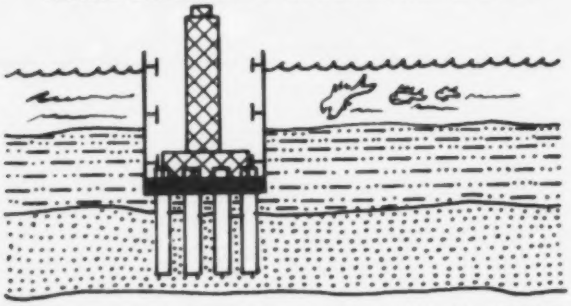
Coffердams are used to exclude water from foundations for any type of structure. Figure No. 2-6 illustrates how a sheet pile cofferdam is used to permit excavation, construction, and backfilling for a large bridge pier. Photo No. 2-4 shows a smaller, easily-constructed earthfill cofferdam used to exclude the water during construction of smaller bridge piers.



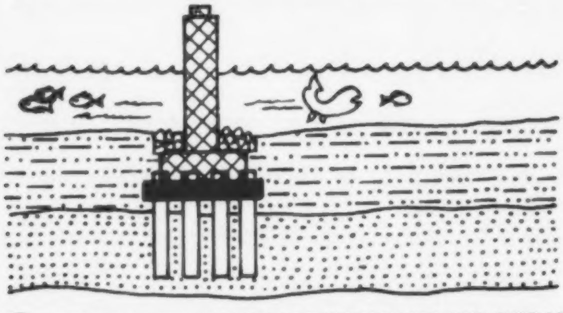
① CIRCULAR SHEET PILE COFFERDAM INSTALLED, FOUNDATION BEING EXCAVATED.



② FOUNDATION PILES DRIVEN. THEN CONCRETE SEAL PLACED UNDERWATER THROUGH TREMIE TUBES.



③ COFFERDAM DEWATERED AND BRIDGE PIER BUILT.



④ FOUNDATION BACKFILLED WITH SAND AND RIPRAP TO UNDERWATER SURFACE. COFFERDAM THEN FLOODED AND SHEET PILING REMOVED.

Figure No. 2-6 - Use of Cofferdam To Permit Installation of Bridge Pier and Prevent Runoff of Sediments During Construction.

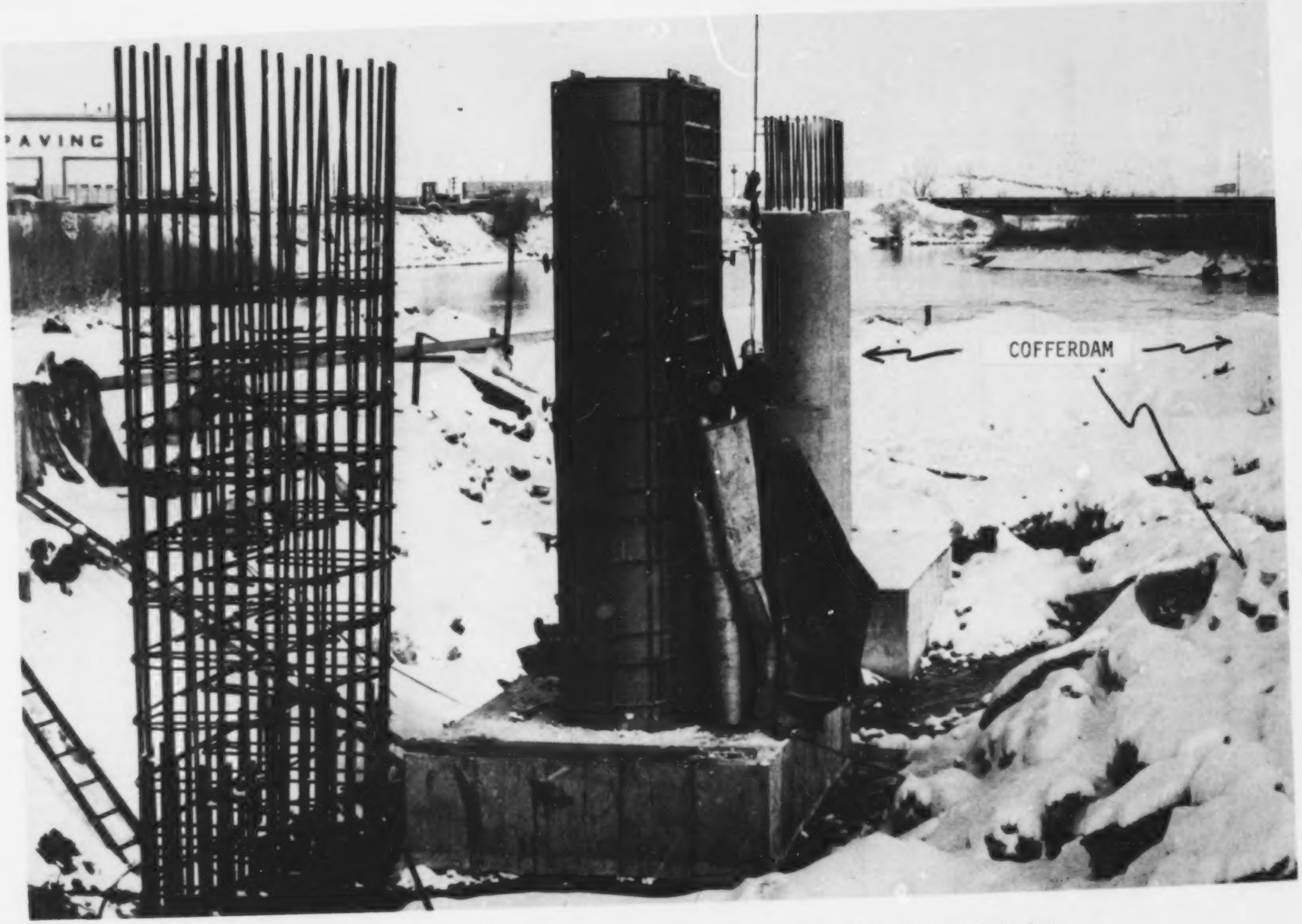

PAVING
COFFERDAM

Photo No. 2-4 - Small, Easily-Constructed Earthfill Cofferdam Used to Exclude Water During Construction of Bridge Piers. (Wyoming Highway Department)

Protecting Masses of Emplaced Dredged or Fill Materials From Erosion

Surface protection must be provided to any mass of emplaced dredged or fill materials if it contains particles small enough to be eroded or transported by the action of rainfall, runoff water, or wave action. Protection from streamflow or wave action can be provided by rigid structures such as concrete, stone, or wood retaining walls or panels and relatively flexible, as well as permeable blankets of rip-rap or armor stone, systems of rock-filled wire mesh baskets (gabions), tree or brush mats, and other materials. Long term protection from rainfall, above the ordinary high water mark, can be provided by adequate vegetative cover. Temporary protection can be obtained with layers of organic or chemical mulches, by burlap netting, or plastic sheeting.

In order to prevent erosion of fill materials and changes in water flow, fill placed into subaqueous trenches should not be allowed to extend above the adjacent underwater ground surface. Often, erosion protection such as rip rap also may be needed. (See rip rap protection on Sketch No.4 of Figure No. 2-6).

Rigid Fill-Protecting Structures

These rigid structures function to retain as well as protect the fill material behind them and to reduce the extent of an individual fill needed for a particular purpose. Photo No. 2-5 shows reinforced concrete retaining walls for a bridge in the forest area. The angular wing walls channel water under bridge as well as provide erosion protection for the fill behind them.

Figure No. 2-7 shows a sketch of another type of retaining and protecting structure, consisting of layers of compacted earth reinforced with horizontal strips of metal. The earth layers are compacted on the strips and friction (without slippage) between the earth and the strips provides strength for the entire unit. Tensile forces are absorbed by the reinforcing strips and earth movement is therefore controlled by this stiffer material. The concrete panels function to protect the earth from erosion by water and allow free drainage of water from the fill (Photo No. 2-6).

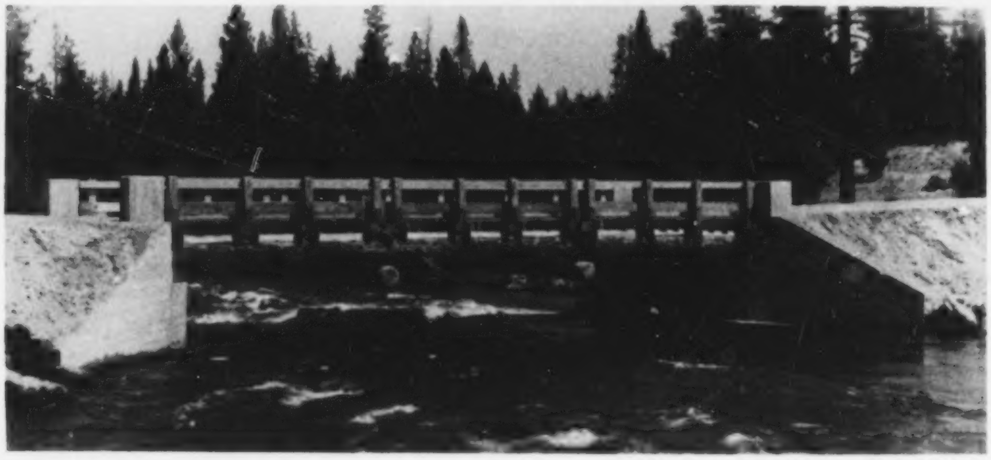


Photo No. 2-5 - Bridge in Forest Area with Abutments Supported and Protected From Erosion By Concrete Retaining Walls (U.S. Forest Service).

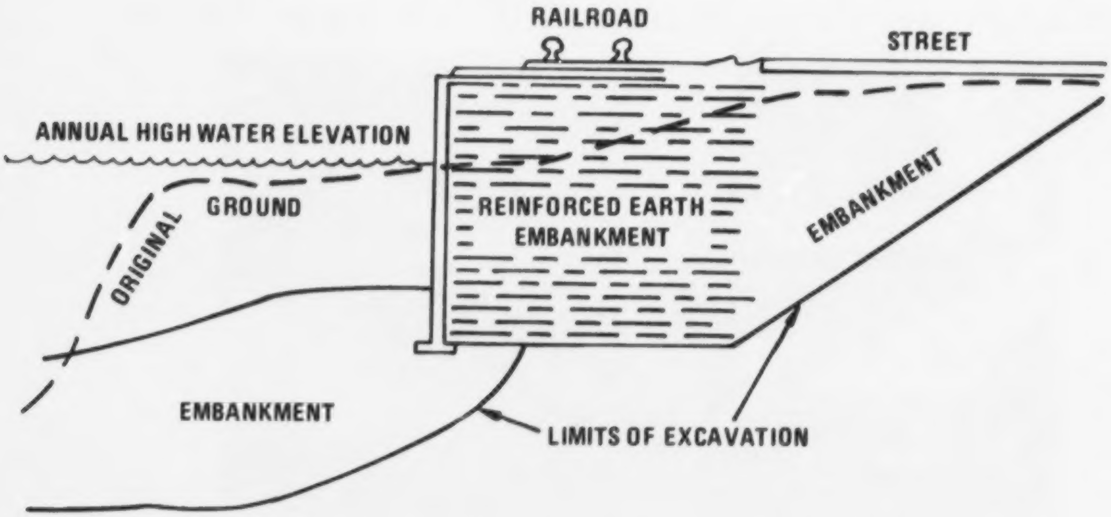

RAILROAD
STREET
ANNUAL HIGH WATER ELEVATION
ORIGINAL
GROUND
REINFORCED EARTH EMBANKMENT
EMBANKMENT
EMBANKMENT
LIMITS OF EXCAVATION

Figure No. 2-7 - Reinforced Earth Embankment, Protected From Erosion By Concrete Panel Face, Was Completed Behind Cofferdam Which Excluded Creek (After Reference No. 24).

Photo No. 2-6 - Concrete Panel Facing For The Reinforced Earth Embankment Showns in Figure No. 2-7 (Reference No. 24).

Concrete facing that does not function as a retaining structure can also be used to provide surface protection for masses of fill materials (See Photo No. 2-7). It generally is formed of slabs of reinforced concrete with the joints between them sealed with plastic fillers. Open cracks or holes which develop must be sealed promptly or the action of surface water and waves may displace or break up the slabs. Openings to relieve hydrostatic pressures behind the panels may be needed to prevent failure.

Photo No. 2-7 - Precast Concrete Panels Protect Slope From Erosion (Reference No. 4).

Flexible Fill-Protecting Structures

Rip-rap should consist of hard, dense, durable angular rocks. They protect underlying material from the erosive energy of moving water and increase the surface roughness of the bank to reduce the velocity of moving water and cause deposition (See Photo No. 2-8). The rock can be placed in a layer upon an exposed slope by machine or by hand.

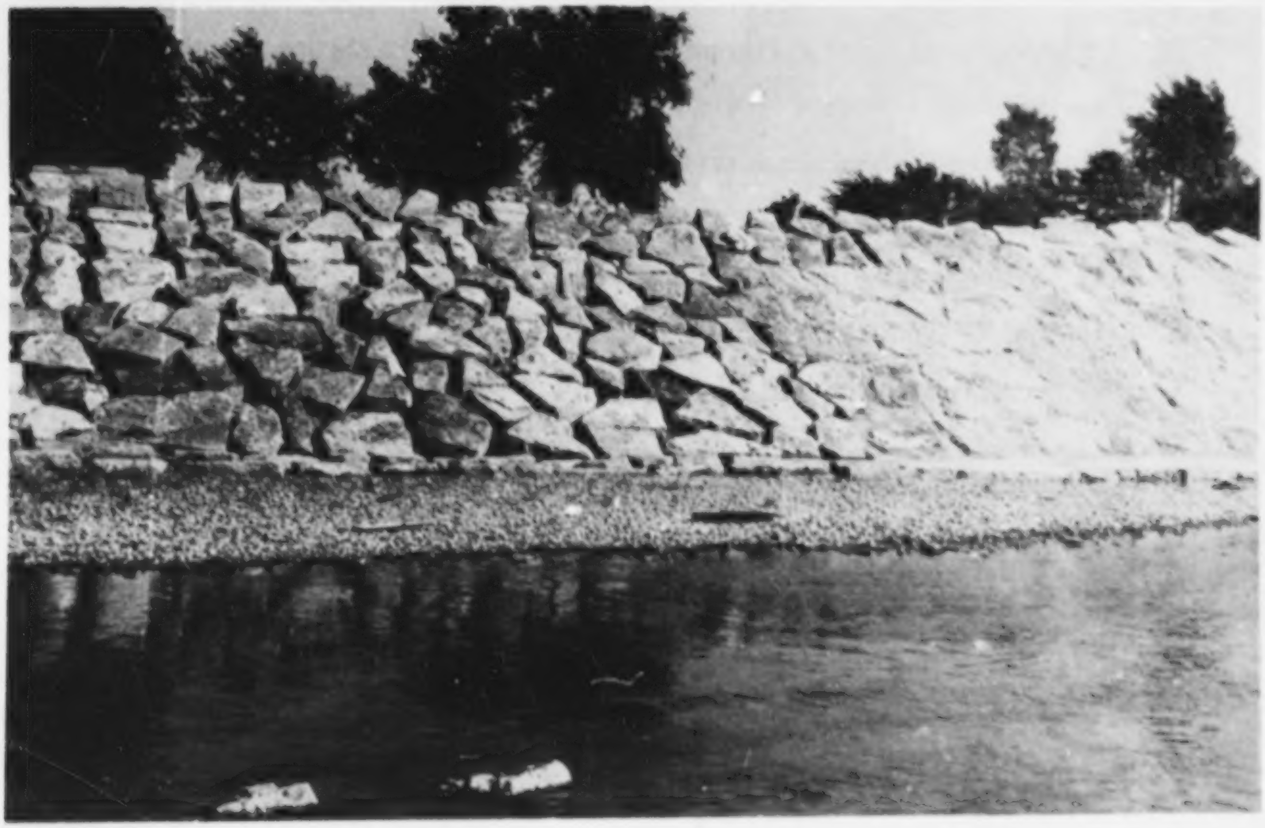


Photo No. 2-8 - Carefully-Placed Rip-Rap "Armor" To Protect Roadfill From Stream Erosion. Material To The Right Has Been Sealed With Grout (A Thin Mortar).

The thickness of the rip-rap blankets (layers) needed depends upon the steepness of the slope upon which they are to be placed; velocity of water flow or severity of wave action expected; methods of placement; and the size, shape, and specific gravity of the rock used. Size of the material will be related to the velocity and direction of flow. Some sources suggest that the thickness of the blanket should be about 1.5 times the diameter of the smallest "immovable" rock if the rip-rap is hand placed, and 1.9 times that diameter if it is "dumped" (Reference No. 9). A reduced thickness can be achieved if compaction techniques are used on the rock such as "plating" with a large flat weight. This densifies the rip-rap blanket and smoothes its surface. Provisions should be made to ensure that the toe area is secure from scour action by currents to prevent lateral sliding of the entire blanket (See Figure No. 2-8). An underlying filter blanket of sand and gravel of fine-mesh filter fabric should be provided beneath the rip-rap to prevent upward movement of the protected materials through voids between the larger rip-rap blocks.

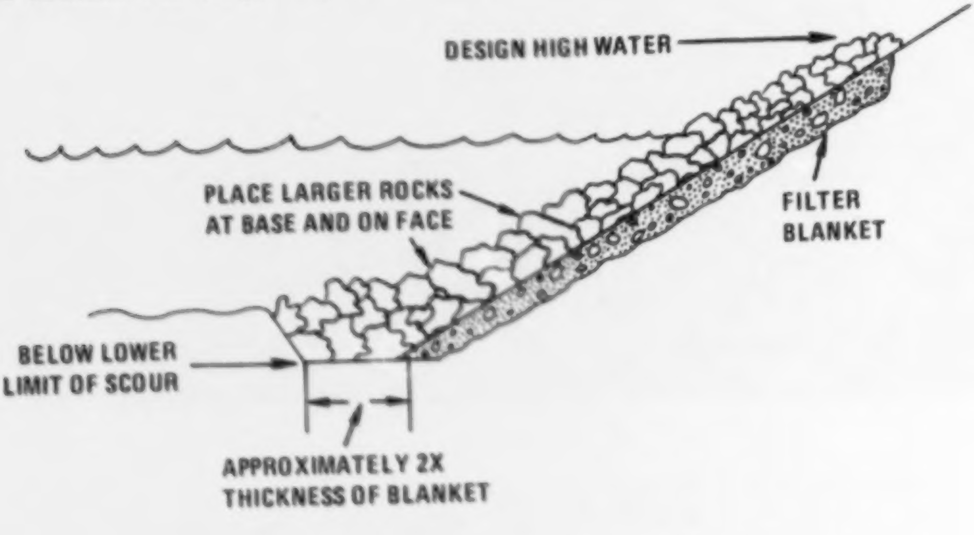

DESIGN HIGH WATER
PLACE LARGER ROCKS AT BASE AND ON FACE
FILTER BLANKET
BELOW LOWER LIMIT OF SCOUR
APPROXIMATELY 2X THICKNESS OF BLANKET

Figure No. 2-8 - Rip-Rap Blanket Protecting Slope From Erosion By Current and Wave Action. Note Filter Blanket. (After Reference No. 9).

If blocks of rock large enough to remain in place during high velocity flows or heavy wave action are not available, smaller rocks can be bonded together after placement by grouting (cementing). These grouted blankets, with the rocks cemented to one another, do not have to be as thick as loose rip-rap and will remain in place upon much steeper slopes (See right-hand side of Photo No. 2-8). Wire mesh also can be used to stabilize rip-rap when small-sized stone is used. The mesh should be pinned in place using staples made of reinforcing rods and its lower edge held down with a weighted pipe or similar stabilizer (Figure No. 2-9). Vegetation often establishes itself in rip-rap blankets above high water where sediment particles have filled in voids between the rocks to form soil.

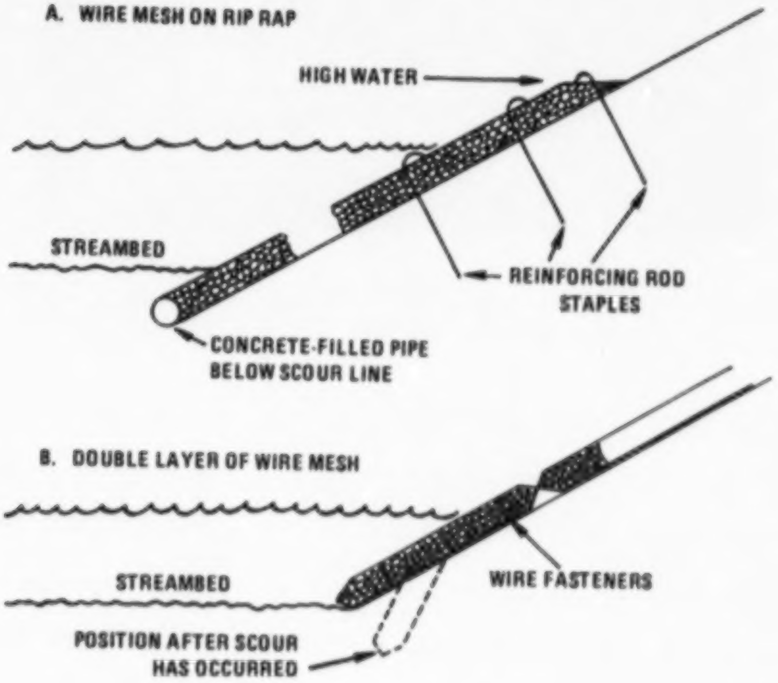

A. WIRE MESH ON RIP RAP
HIGH WATER
STREAMBED
REINFORCING ROD STAPLES
CONCRETE-FILLED PIPE BELOW SCOUR LINE
B. DOUBLE LAYER OF WIRE MESH
STREAMBED
WIRE FASTENERS
POSITION AFTER SCOUR HAS OCCURRED

Figure No. 2-9 - Wire Mesh Stabilizing Small Rock Blanket (Reference No. 9).

Rip-rap also can be placed into pre-constructed wire mesh baskets called "gabions". The mesh should be small enough so that most of the rock cannot pass through it. Strength required of the wire mesh depends upon the desired life of the blanket and the type of support the system of baskets is to provide. Gabions can be arranged, or stacked to form steep, or near vertical walls protecting a fill (See Photo No. 2-9).

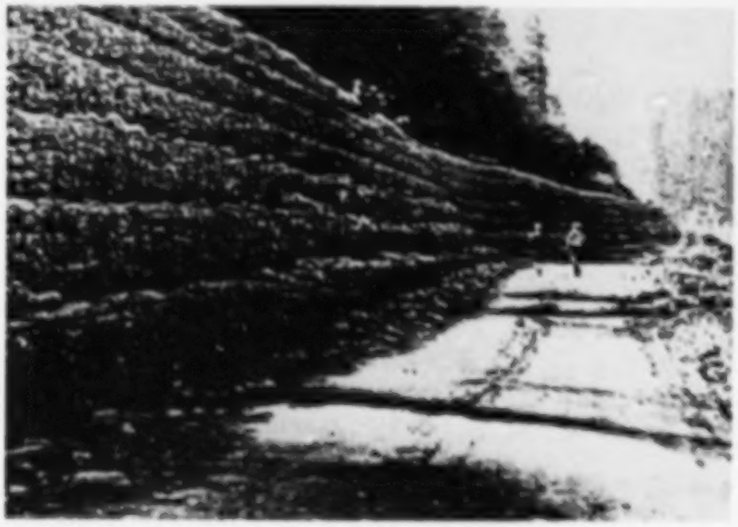


Photo No. 2-9 - Completed Gabion Wall Illustrating How Steep Protective Structures Can Be Made (Reference No. 3).

Brush mats, planted with shrubs and protected at the toe with rock rip-rap also have been used to protect the surface of exposed fill materials above normal water levels (Figure No. 2-10). The mat itself has a short life; its principal purpose is to provide protective covering for both the slope and the shrubs and trees planted beneath. Slopes should be planted before matting is installed, preferably in the spring or other appropriate season. Stakes used for anchoring the brush mats may be made of "live" woody plant material which can take root, grow, and protect the slope when the mat breaks up.

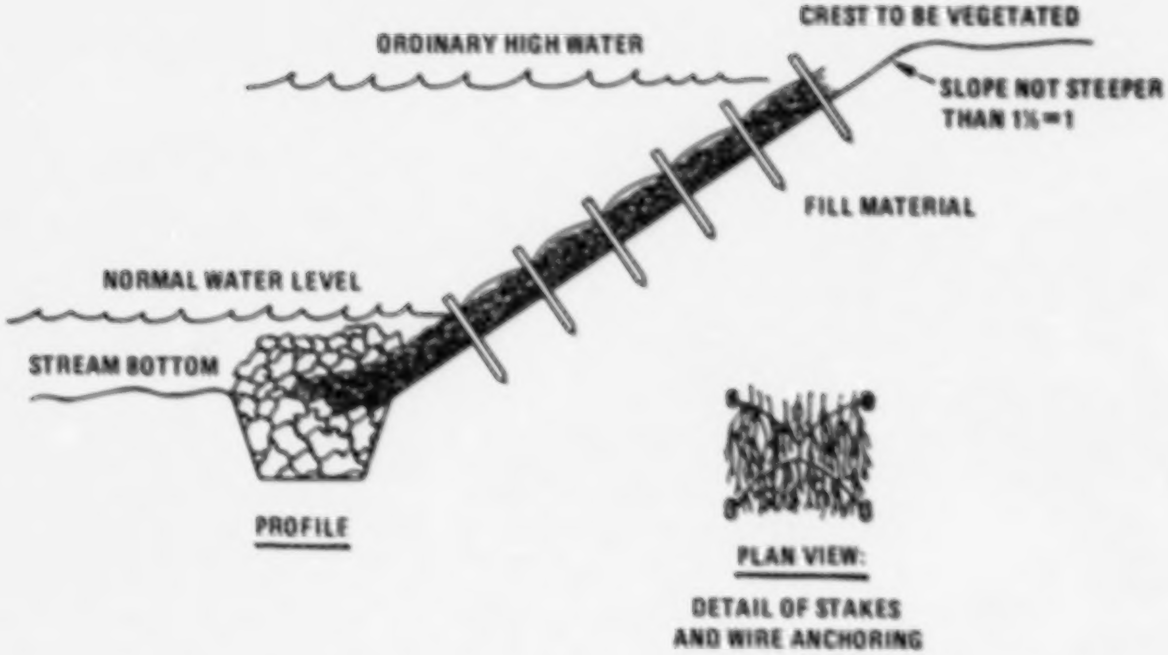

CREST TO BE VEGETATED
ORDINARY HIGH WATER
SLOPE NOT STEEPER THAN 1½=1
FILL MATERIAL
NORMAL WATER LEVEL
STREAM BOTTOM
PROFILE
PLAN VIEW:
DETAIL OF STAKES AND WIRE ANCHORING

Figure No. 2-10 - Brush Mat Protecting Slope From Erosion. Brush Planted Beneath Mat Provides Long-Term Protection. (After Reference No. 12)

CHAPTER 3

ENSURING CONTAINMENT OF POTENTIAL POLLUTANTS WITHIN MASS OF DISCHARGED DREDGED OR FILL MATERIALS

Naturally-occurring materials interspaced through masses of dredged or fill materials can become pollutants when discharged, or placed, into a new environment. Their use should be avoided if at all possible. They may include such minerals as gypsum (calcium sulfate), pyrite (iron sulfide), salt (sodium chloride), or other substances. Contact of these materials with air and water can cause changes in their chemical composition and/or put them into solution. Unless Best Management Practices similar to those presented in this chapter are implemented to restrict their contact with air and water and prevent the runoff of dissolved materials, nearby water bodies will be subject to pollution. If any of these materials are suspected, geologic studies should be initiated to identify their location, concentration, and extent so that sources of alternate materials can be located.

In arid areas, sometimes the only available fill materials consist of clay shales of marine origin which may contain quantities of gypsum, salt, or similar soluble minerals in veins or disseminated throughout. These soluble materials result from the evaporation of seawater following deposition. Many dry lake deposits in enclosed basins in arid areas contain high salt contents as do the sediments adjacent to the lakes. Any area where extensive evaporation of water has taken place should be suspect. If fills for bridges, culverts, or other facilities to be placed into water bodies are obtained from such geologic units, they must be considered potential sources of pollution.

Pyrite and other iron sulfide minerals, occur in many areas and in different types of rock which can be used for fill materials. Soft easily-excavated sedimentary rock that is readily usable for fill or hard consolidated materials that require blasting such as rip-rap may contain quantities of iron sulfides. Sulfides are readily oxidized when exposed to air, moisture, and bacteria (Thiobacillus) and can create high concentrations of mineral acids. As the acid solutions flow over, or through, adjacent fill materials, they dissolve heavy metals such as iron, manganese, copper, aluminum, and zinc to add to the pollution problem.

Formations containing any of these types of substances may also underly alluvial beds of rivers that are being dredged or source (borrow) areas where fill materials are to be obtained. If the poor quality materials can be identified, isolated, removed, and properly disposed of separately from the principal mass of dredged or fill material to be used, they will not pose a threat to the environment. If they are interspersed through the main body of materials, however, they probably cannot be separated and will cause the entire body to be pollution threat. This situation probably is more characteristic of fill than of dredged materials since most river beds are formed on deep freshwater alluvial deposits that do not contain such "natural" pollutants.

To prevent pyrite, gypsum, or salt-bearing dredged or fill materials from causing possible water pollution when discharged or placed into water bodies or in wetlands, Best Management Practices should be in use to contain these materials and prevent their contact with air and water. The specific BMPs to be considered could involve placing the poor quality materials within relatively impervious layers (blankets) or barriers of compacted and relatively impervious materials. (See Figure No. 3-1).

On steep fill slopes, where stability may be a problem, or quantities of impervious soils for blankets are limited, gabions (wire mesh baskets) of compacted soils may be considered. In these cases, the impervious blankets are thinner, but can also function to resist failure due to the tensile strength of the baskets. Ensuring the placement of impervious materials effectively into voids between gabions will be critical with this type of barrier. If fill material being contained beneath the gabion blanket, is extremely coarse-grained, a filter consisting of sand and gravel or filter cloth may be necessary to prevent downward movement and loss of the fine-grained impervious blanket materials into the fill below. (See Figure No. 3-2).

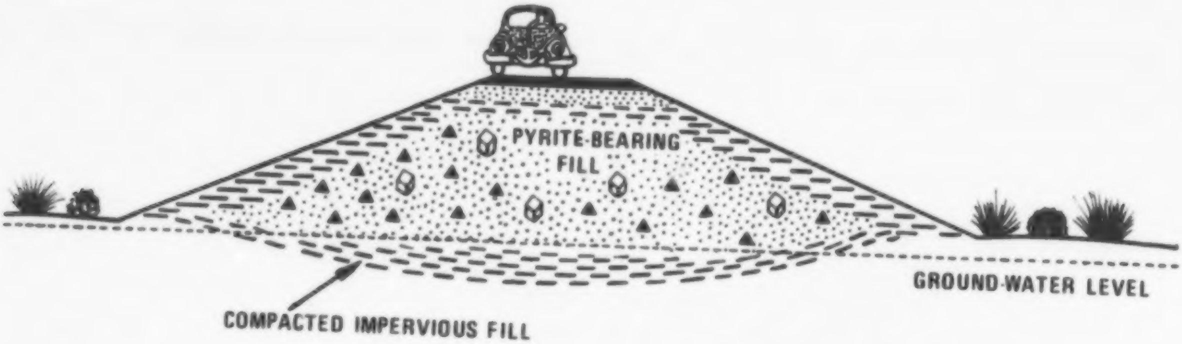


Figure No. 3-1 - Impervious Fill Surrounding Roadfill Containing Pyrite Restricts Contact With Water and Air.

The basic premise for using impervious blankets and seals is to provide water and air barriers to isolate the materials containing potential pollutants and prevent chemical actions from occurring. When pyrite or other sulfide minerals are involved, excluding the air and water also acts to prevent breakdown of individual particles in the fill and the exposure of fresh pyrite crystals to the elements. The impervious materials also provide exterior surfaces that are relatively easily vegetated and require little future maintenance.

An additional, and supportive, BMP available involves the chemical neutralization of potential pollutants . On some projects, agricultural lime has been blended with pyrite-bearing fill or placed in a layer on outer surfaces under the impervious soil. The addition of the lime will minimize the production of acid, partially neutralize acid that is being produced, and prevent toxicity to vegetation when impervious blankets are thin (See Figure No. 3-2).

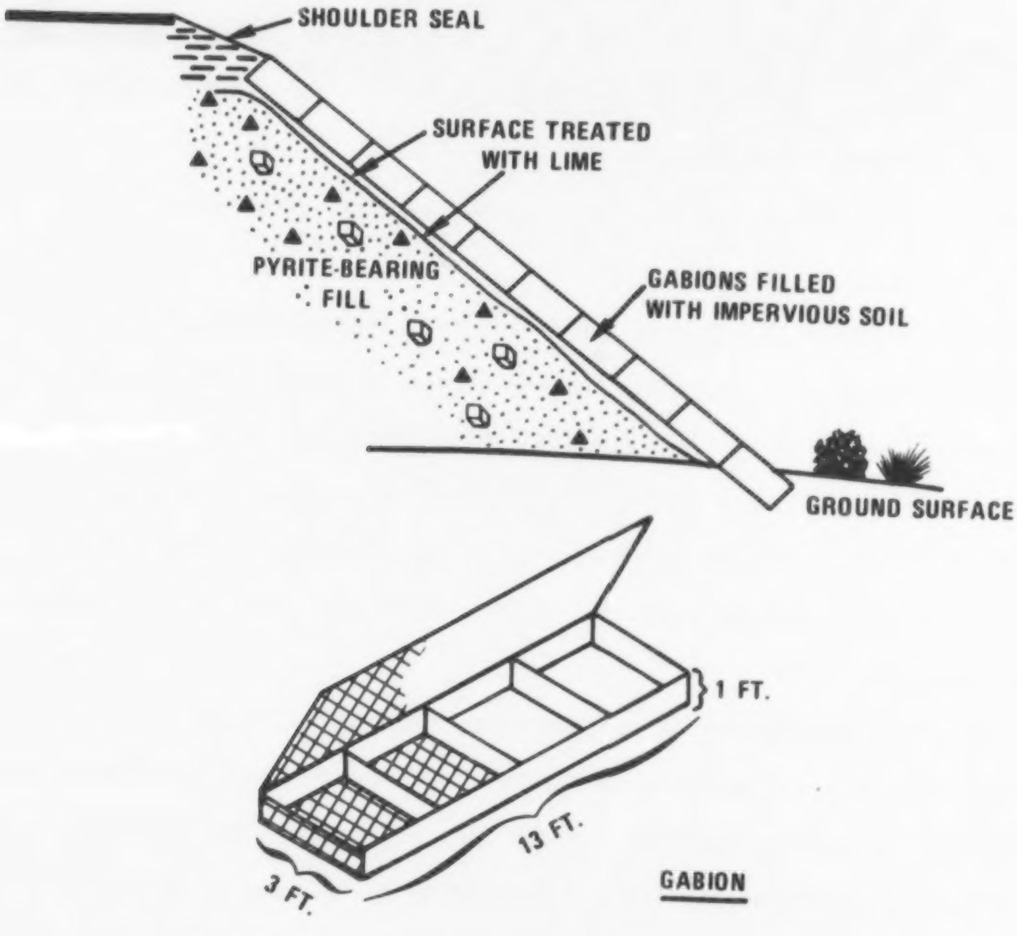

SHOULDER SEAL
SURFACE TREATED WITH LIME
PYRITE-BEARING FILL
GABIONS FILLED WITH IMPERVIOUS SOIL
GROUND SURFACE
1 FT.
13 FT.
3 FT.
GABION

Figure No. 3-2 - Earth-filled Gabions Providing An Impervious Blanket On Roadfill Containing Pyrite (After Reference No. 29).

Impervious blankets function as barriers which only restrict, not stop, the movement of water into or out of the materials they are designed to isolate. If differential water levels are maintained on either side of these barriers for a long enough period of time, water will move through them, but only at a slow rate, due to their low permeability. Consequently, the estimated time intervals that differential water levels are to be maintained on either side of impervious blankets or barriers, as well as their degree of permeability and thickness, must be determined to provide adequate protection. If only rainfall and sheet runoff of short duration are to be excluded, relatively thin blankets of only moderately water-tight materials may be adequate. In cases where large differences in water levels can occur for long periods of time on either side of a blanket or barrier, it must be a thick, highly-compacted impervious unit. If water finally moves out of the contained fill after being degraded by the soluble materials in it, it will be at such a slow rate that it probably will be diluted by the faster-moving water outside and not pose a threat to its quality.

CHAPTER 4

PROTECTING HABITAT CONDITIONS AND PROVIDING FOR FISH AND WILDLIFE PROPAGATION

Water-retaining structures such as dams and reservoirs, regardless of their size, often function as complete barriers to the movement of aquatic life and water-dependent wildlife. Linear fills across wetlands or water bodies such as railroad or highway embankments, causeways, or even canals and aqueducts can restrict movement of fish or other creatures unless adequate facilities have been provided for passage through or under these structures. Deer, quail, foxes, rabbits, and other wildlife can cross over or travel along these linear facilities, but only with extreme danger to their lives. Permits for the discharge or placement of materials to form such structures may be required under Section 404 if changes in the use of nagivable waters are involved, flow or circulation impaired, or reaches reduced. In such cases application of appropriate BMP's may be a condition for obtaining a permit. Best Management Practices to prevent or minimize such environmental impacts should include providing effective passageways for aquatic animals and other wildlife through, over, or possibly around such structures, preventing wildlife and other creatures from gaining access to areas of potential danger; and minimizing adverse habitat changes caused by the discharge or placement of the dredged or fill materials.

A brief discussion of some of the presently available practices is presented here. At present, BMP development in this environmental problem area is an art rather than a science and many of the techniques and practices have not been proven fully effective. There is no intent in this document to imply that these are the only practices available or that they will accomplish the desired purposes in all areas and situations Additional and more detailed information on BMP's for protecting habitat conditions and providing for fish and wildlife progation is presented in the References on Pages 6-1 through 6-4.

Creating Passageways For Aquatic or Water-Dependent Wildlife Through, Around, Under, or Over Structures

Discharge of water from reservoirs is accomplished through outlet pipes or penstocks of some sort which extend through or under the retaining structures, surface spillways that extend around the end or over structures, and diversions that channel the water around dams for further transmission. Generally, when water moves through these structures it does so at high velocities and the passage of aquatic life through them is difficult or impossible.

Linear fills extending across wetlands or adjacent water bodies can restrict the movement of aquatic life and water dependent wildlife into or within such areas. The restrictions on wildlife movement can be minimized or eliminated by providing passageways through embankments in areas where animals are known to habitually travel.

There are practices available to provide for the passage of migrating fish through or around water-retaining structures. They involve such facilities as fish ladders, fish conduits, and similar units. (See Photo No. 4-1). Once past the structures, fish are free to travel upstream to spawning beds. For some structures, fish ladders lead to holding ponds where fish are collected and transported to spawning areas. If the effects of a dam or reservoir on the habitat of anadromous fish will be severe,

Photo No. 4-1 - Salmon Migrating Upstream Use Fishladder Facility To Bypass Dam (U.S. Bureau Of Reclamation).

manmade spawning beds may be designed into the project. Additional facilities then are required to direct and channel the fish to these spawning beds. They can include electric barriers, fish ladders, and bypass channels.

Sometimes a reservoir floods spawning beds for anadromous fishes such as salmon. In these cases fish ladders, or other by-pass structures can terminate at fish hatcheries where the migrating fish are collected, killed, and the roe obtained. The roe is fertilized and then placed in the hatchery under controlled conditions until the fish are hatched. After having reached an appropriate stage in their development, the fish are released into the river downstream of the dam to migrate back to the ocean and complete the age-old cycle of migration that their parents had initiated.

The generation of power at hydroelectric dams results from the movement of reservoir water through penstocks and turbines to downstream areas. Migrating young fish may suffer significant losses when passing through the turbines unless these facilities have been designed for fish passage. The survival chances of the downstream migrating fish can be increased by providing facilities that bypass them into a gatewell before they enter the turbines and direct them into a channel where they can move safely downstream. Fish ladders or some similar type of structures should be provided to enable returning mature fish to migrate upstream around the dam. Additional and more detailed information on such devices is presented in a document under preparation for the Fish and Wildlife Service entitled "Interim Guide To The Performance Of Fish and Wildlife Habitat and Population Improvement Measures For Western Dam and Reservoir Projects" (Reference No. 22).

Linear Transportation or Conveyance Facilities

The design of passageways through or under linear embankments should be based upon the habits and needs of wildlife in order to become fully effective. Underpasses beneath, or through highway and railroad embankments in wetlands or water bodies probably will be more effective if used in conjunction with fences to help guide wildlife through the openings. Many animals will be hesitant to go through such passageways unless guided and restricted by these fences. Some of them are fully capable of climbing the embankments to cross or travel along the structures. If they are able to do so, their lives will be endangered by vehicles or other hazards.

Passageways for wildlife should be designed to appear as natural as possible to the animals. Their minimum widths and lengths should be based upon the size of the animals involved. Floors should be of earth or other natural materials and skylights or artificial lighting of any kind should be avoided. Photo No. 4-2 illustrates an earth-floored passageway thorough an embankment with fences to channel animals through the structures. In general, facilities for animal passage extend under road or railroad embankments. and over water facilities such as canals and aqueducts. (See Photo No. 4-3).

Photo No. 4-2 - Underpass For Animals Beneath A Highway. Fences At Toe Of Slopes Prevent Their Movement Up Embankment To Roadway. (U.S. Federal Highway Administration).

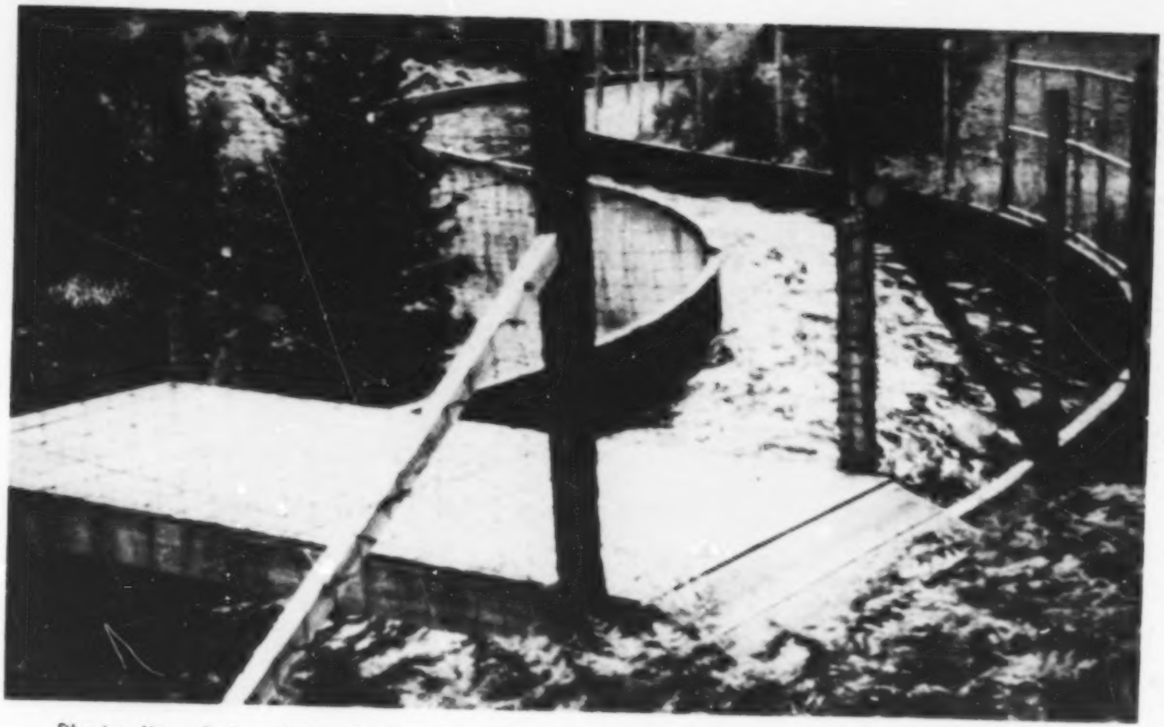


Photo No. 4-3 - Animal Crossing Extending Over Fenced Aqueduct. Wooden Floor Has Not Been Covered With Earth Yet. (U.S. Bureau of Reclamation).

Providing Protective Devices For Wildlife Contacting or Crossing Structures

Aquatic life and water dependent wildlife often place their lives in jeopardy when attempting to pass through, over, or along masses of emplaced fill materials. Some may be sucked into pumps and pumping plants, discharged over spillways, carried through siphons, or trapped in aqueducts or flumes. Others may surmount road or railroad embankments to be killed or crippled by moving vehicles. Fish can also be endangered by spillway flows which cause nitrogen supersaturation of water in spilling basins immediately downstream from the spillways.

Water Facilities

Fish and other aquatic life can be prevented from moving into intakes for water pumps through the use of various types of screens, or barriers. Large pumping plants that draw tremendous quantities of water may need more elaborate protective devices. A louvered protective system for fish is shown in Photo No. 4-4. The fish being carried toward the pumps by the rapid flow of water are kept out of them by the louvered screens. A second set of screens and bypass facilities functions to divert them into holding tanks where they are collected, transported away from the area of influence of the pumps, and then released back into the water out of the danger zone.

Canals, aqueducts, or other water-conveyance bodies often extend across routes used by wildlife to gain access to feeding, refuge, reproduction, or other areas. Animals attempting to cross these facilties, or drink from them, may have their lives endangered. Steep, smooth slopes on canal, aqueduct, or reservoir banks can prevent animals from escaping once they descend. Then, currents in canals and long swimming distances to escape areas in reservoirs can cause additional dangers to threaten the animal's lives. Canals may have siphons, or other structures, and man-made reservoirs often have spillways, outlet works, and penstocks that locally increase current velocities and create other hazards.

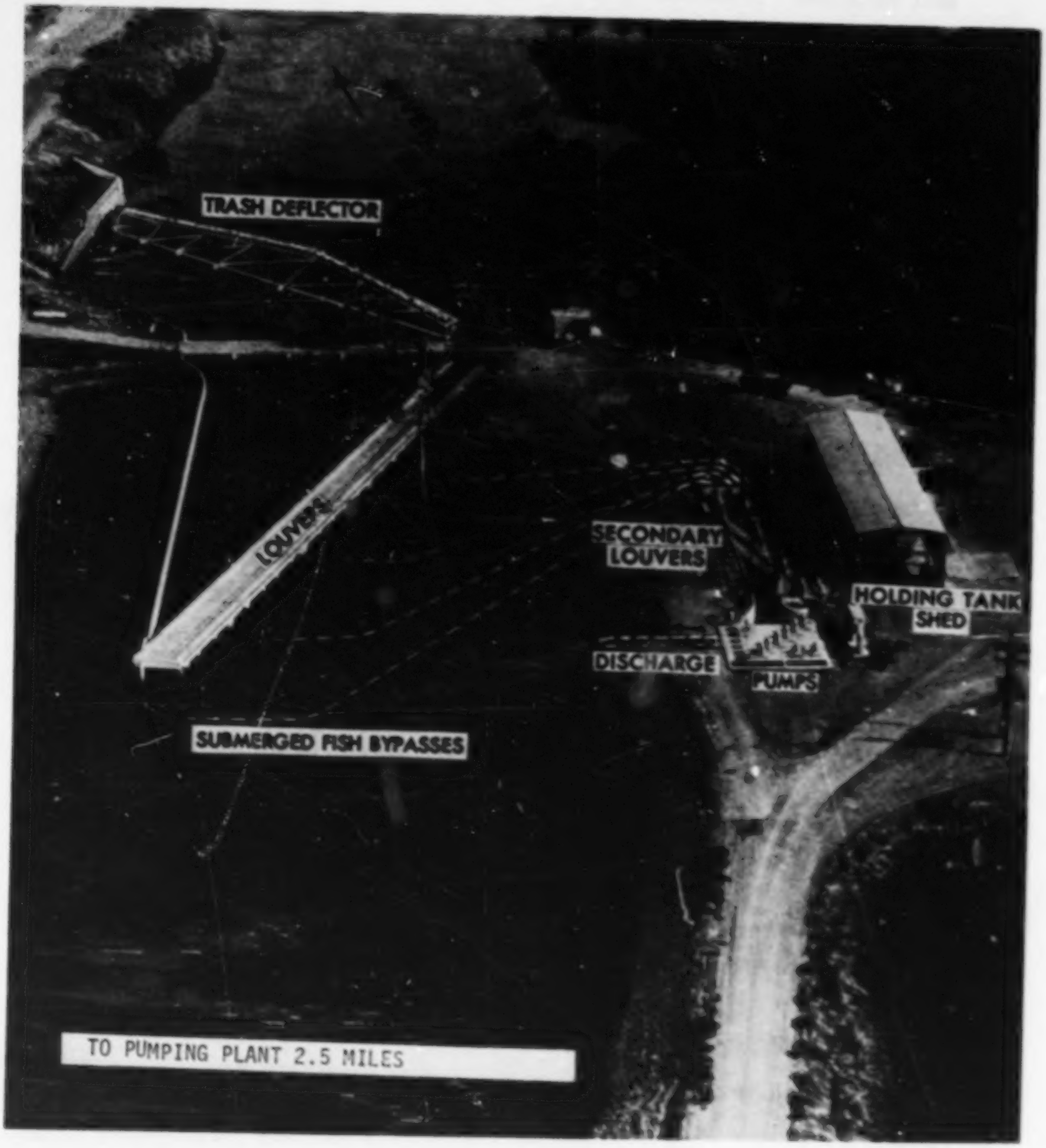

TRASH DEFLECTOR
LOUVERS
SECONDARY LOUVERS
HOLDING TANK SHED
DISCHARGE
PUMPS
SUBMERGED FISH BYPASSES
TO PUMPING PLANT 2.5 MILES

Photo No. 4-4 - System With Two Louvers To Prevent Anadromous and Other Fish From Being Carried Into Major Pumping Plant. They Are Collected In Holding Tanks and Returned To The River. (U.S. Bureau of Reclamation).

Best Management Practices have been developed and can be used to prevent wildlife from being trapped in such structures. Fencing is an effective practice to prevent animals from gaining access to and being endangered by a canal or aqueduct. It is generally expensive, however, and will require crossing facilities such as bridges to be provided for the animals. These crossings must be located at intervals, particularly where predominent migration routes or trails exist. If migration or other movements of animals are restricted by fences without crossing facilities, herds may suffer losses or deterioration in quality due to inbreeding, loss of feed sources, or other problems.

Fences must be designed for the particular animal involved. They should be high enough to prevent animals from jumping over and sturdy enough to prevent them from being torn down. Animal bridges, or overpasses, should also be designed for the animals that are to use them (See Photo No. 4-3). Floors should be covered with natural materials such as soil, sand, or gravel and the crossings limited in width to prevent their use by four-wheeled vehicles.

Pipelines rather than open canals should be considered in wetlands to minimize danger to wildlife, particularly in areas where wildlife tend to migrate or travel. When they are buried, crossing by animals is greatly facilitated.

Where covered pipes, fencing, and other practices are not feasible or fully effective in preventing wildlife from entering a canal or aqueduct, entrapment and escape structures may be placed into the facility. Many of these structures are designed also to enable wildlife to enter the canal, descend a slope to obtain water, and then return up the slope (See Photo No. 4-5).

The escape structure shown in the canal in the photograph consists of a ramp constructed in an indentation in the steep canal bank with an angled barrier or other device to divert swimming animals into the ramp. Other, probably less-effective structures have been devised and used. They may be temporary or permanent. Layers of soil have been placed, as temporary escape structures, down canal sides while sandbag layers have provided more permanent ones. Concrete steps, or other types of ramps, and accompanying facilities can be designed into the canal slopes to function as permanent and effective escape units.

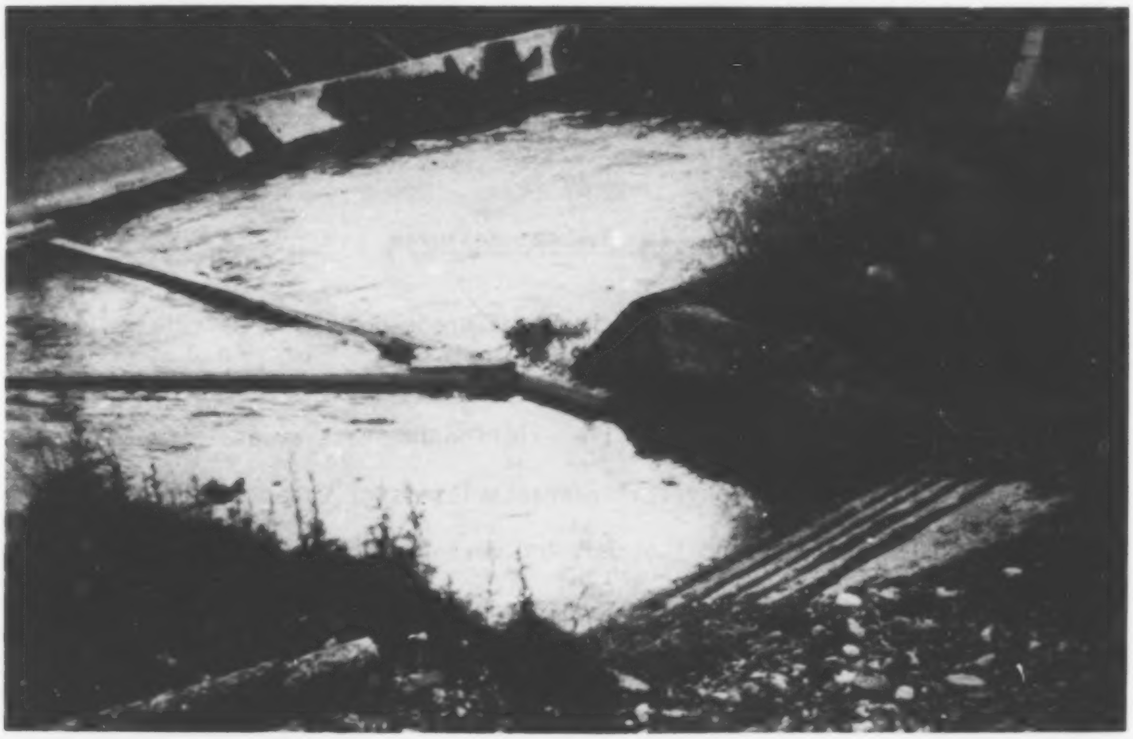


Photo No. 4-5 - Concrete Escape Ramp With Low Slope (4h:1v) Built Into Indentation In Steep-Sided Canal. Note Timber Boom That Directs Swimming Animals Into Ramp. (Bureau Of Reclamation).

Transportation Facilities

Causeways extending across wetlands for highways, particularly large freeways, often are fenced at their right-of-way boundary. Animals can gain access to these structures through one avenue or another and place their lives in danger from passing vehicles. As they find their escape from the noisy vehicles on the roadway blocked by the fencing, they become panicked which places them in even more danger. Facilities have been developed and installed into the fences at certain localities to permit animals to escape back into the wetlands and safety. They consist of structures composed of baler tines and angle irons which allow animals to escape from the roadway, but prevent re-entrance.

Habitat Improvement Measures

Any structure formed by the discharge of dredged or fill materials into wetlands or water bodies changes to some extent the regimen of aquatic life and other water dependent wildlife existing in these areas. Stream-flow regimes and the chemical or physical characteristics of water can be altered, water depths changed, dry land flooded, and perhaps flooded lands dewatered. As a result of these changes, aquatic life and wildlife in the area will be affected. They may move to different localities or be replaced by other types of creatures.

The effect and magnitude of these changes may be minimized by habitat improvement Best Management Practices which remedy the problems or provide substitute areas to maintain or provide for the propagation of existing aquatic life and water oriented wildlife. They may include proper management of water flow and circulation, and the provision of nesting, spawning, nursery, resting or feeding areas for aquatic life and water-oriented wildlife.

Proper Water Management

Dams are placed across streams to impound water for further use by man. Excess quantities of water from flood flows can be stored for later use. Peak flood flows can be reduced and low flows increased by proper operation of dam facilities. If too much water from a reservoir is diverted into other areas, however, or excessive quantities of water released for use during other periods of time, insufficient water may be available to maintain storage and flow requirements for aquatic life during dry periods of the year.

During the design, construction, and operation of dams and other water projects, the flow requirements to support aquatic and other water-dependent wildlife in downstream areas must be considered during the feasibility, design, construction, and operation stages and sufficient flows made available to meet these needs. Sufficient water will be needed also for flood releases which function as natural scouring media in the channel farther downstream Otherwise sediment loads brought into the main streams by tributaries may build up into deltas at their junctions. If they form large enough deposits, they can obstruct or restrict the main channel flows. Spawning gravels also can be ruined by these excess sediment loads if they have not been periodically flushed out by high flows.

Dams and reservoirs on coastal streams having anadromous fish populations must be designed to make available sufficient quantities of water to flush open sandbar barriers formed by offshore currents across the mouths of these streams. Unless sufficient high flows can be provided to open these bars, anadromous fish will not be able to enter the channel for further upstream migration and spawning.

Preventing Detrimental Physical or Chemical Water Changes

Water discharging over the spillway of a dam has quantities of air entrained in it. As it plunges rapidly to depths in a stilling basin, or plunge pool, hydrostatic pressures increase and force the constituents of the entrained air into solution in concentrations exceeding normal saturation values. This is termed "supersaturation". Supersaturation also can occur in the bodies of fish swimming at depths and cause death. Nitrogen supersaturation causes most of the problems as it comprises approximately 80% of the entrained air. The oxygen content (20%) in the fishs' bodies is mostly be metabolized and other gases are too minor to affect them.

Anadromous fish populations in rivers of the northwest have suffered from nitrogen or "gas bubble disease". If they swin at depths greater than 12 feet in the nitrogen-supersaturated water, the fish are not affected by the disease, since the external pressure prevents the gas from forming bubbles in their bodies. As they swin at shallower depths, however, up fish ladders or near the surface, the nitrogen gas pressure within the fish's body exceeds the external water pressure and bubbles form. Blisters and bubbles form under the skin, on the body and fins, on and under the gill covers, and in the mouth and head.

The nitrogen problem is most serious in the Columbia-Snake River reservoir system of the northwest because the river waters have an overabundance of dissolved air in them and most of the spillage occurs during the principal upstream and downstream migration periods for the fish.

Since spillway discharges must plunge to depths to cause nitrogen supersaturation, BMPs for preventing this problem involve designing or modifying spillways to cause the flows to be "flipped", as they are discharged, some distance downstream. Upturned deflectors, cantilevered extension or "flipbuckets", can be designed for spillway terminal structures to deflect the water in a downstream direction and prevent the discharge from plunging deeply (See Figure No. 4-1). The water can even be caused to fan out into a thin sheet through the use of a flaring device.

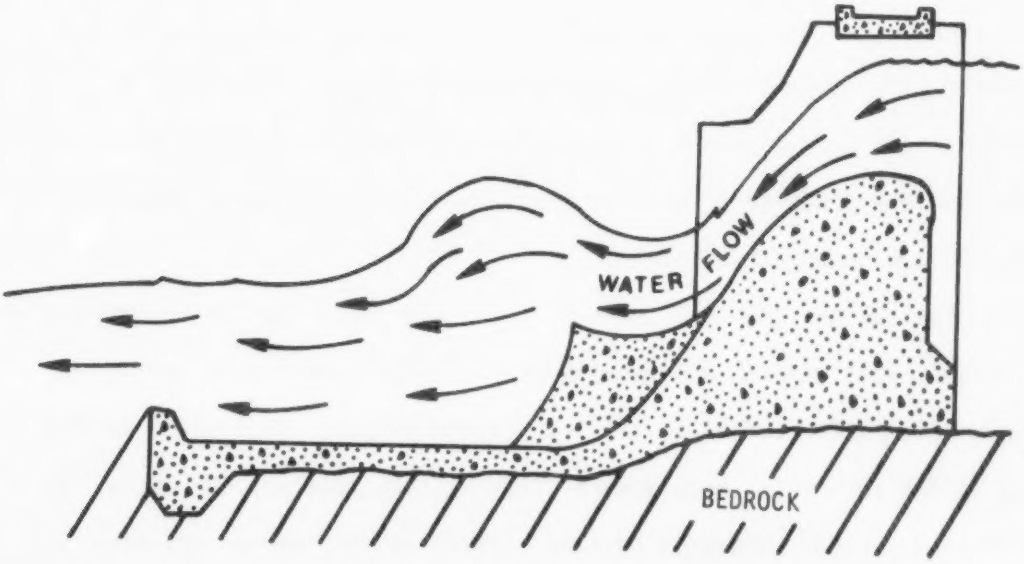


Figure No. 4-1 - Spillway Showing How "Flip" Structure Prevents Flow From Plunging To Depths.

Other Best Management Practices to prevent nitrogen supersaturation and "bubble disease" can include:

1. Collecting and transporting fish overland through the length of river where nitrogen supersaturation occurs.
2. Decreasing spillway flows by providing additional reservoir storage.
3. Passing water through any available outlet conduit where turbulence will not entrain air.

The physical and chemical character of the water in a stream is generally changed when it is stored in a reservoir behind a dam. When released downstream, this water may initiate detrimental effects on aquatic life and possibly the regimen of the stream. The temperature of released water may be higher than stream water if obtained from the shallow layers of the reservoir and discharged through upper water-level outlets, and lower if obtained from reservoir depths. Water released from outlets deep in a reservoir also may be oxygen deficient. These changes can be detrimental to aquatic life immediately downstream, particularly to cold-water or anadromous fish such as trout, steelhead, and salmon. Existing aquatic populations may decrease or even be supplanted by a new species more adapted to the changed conditions.

The physical and chemical changes in released water can be minimized, particularly with regard to temperatures and oxygen content by providing multiple intakes for outlet facilities. These intakes, located at various depths in the reservoir, regulate releases so that problems are minimized (See Photo No. 4-6). Higher elevation outlets release warmer and more oxygenated water, while lower ones draw from colder water which contains less oxygen. The quality of the releases can be regulated to meet the needs of the aquatic life being protected through a properly designed and operated outlet system.

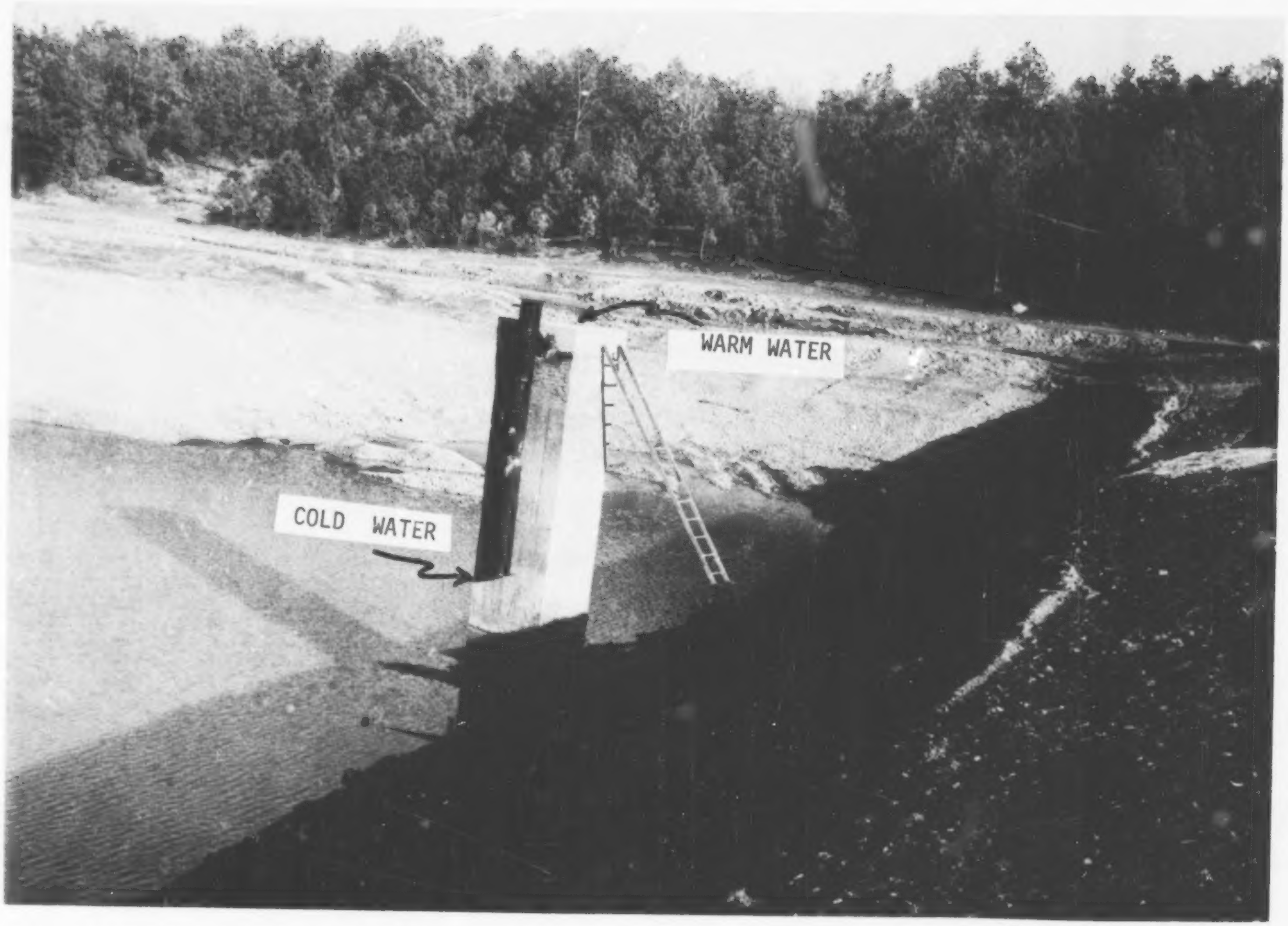


Photo No. 4-6 - Deep-water Intake Installed On Old Concrete Outlet Riser. Colder Water Enters Lower End of Pipe From Depths. Warmer Water Enters From Top of Concrete Section (U.S.D.A., Soil Conservation Service).

CHAPTER 5

ENHANCEMENT --THE REPLACEMENT, RELOCATION, OR RECONSTRUCTION OF EXISTING ENVIRONMENT

In certain extreme situations, the discharge of dredged or fill materials into water bodies or wetlands may be necessary although the potential for severe damages to or destruction of the existing local environment may be recognized. When this situation occurs, the only alternative that remains is to consider, as a Best Management Practice, the enhancement or replacement of the existing or a similar type of environment to compensate for habitat loss. In other words, artificially create an equally productive area of new aquatic environment for that damaged or destroyed. As these practices are in the development stages, limited information is available regarding their long-term effectiveness, particularly in wetlands.

If a significant percentage of the aquatic area becomes dry land due to the discharge and the use changed, the flow or circulation of the waters impaired, or the reach of a water body reduced, a permit may be required in accordance with the Section 404 program.

Creating environmental conditions in a new area that will be similar to the natural environmental conditions that occurred in an adjacent area is extremely difficult since they result from numerous interrelated surface and sub-surface hydrologic, geologic, topographic, climatic, plant and animal, and other factors. Changes in one or more of the factors may set up a chain reaction which results in changes ensuing in others. The end result of the changes may be unpredictable and detrimental unless sufficient data are available concerning the entire system.

Wetlands

In wetlands, water is the dominating factor in determining the nature of soil development and the types of plant and animal communities occurring there. Wetland soils are saturated periodically due to fluctuations in surface or ground water elevations. As a result, knowledge of water flow into and through the wetlands is essential for evaluating the practicality of enhancing or replacing an area of wetlands. The regimen and depth of water flow and the physical and chemical character of the soils in the new wetlands should duplicate, as closely as possible, those in the area damaged by the discharge or placement of dredged or fill materials. Vegetation and animal life characteristic of the adjacent wetlands may quickly migrate into the new area and establish themselves. If they do not, re-establishment by transplanting pioneer species probably will be essential to enable the new wetland to quickly establish itself and, through successional processes, produce and support climax communities of aquatic life and other wildlife.

The long-term stability of a newly-created wetland should receive prime consideration. All of the factors brought into play to create it must operate conjunctively to maintain its existence and productivity. On a long-term basis, the net energy inflow into the wetland from surface and ground waters transporting nutrients, sediments, and other materials necessary for maintenance of life should be made approximately equal to the outflow. In wetlands where the energy inflow comes from both salt water sources in coastal areas and fresh water in upland areas, the system is extremely difficult to assess and to duplicate. The interplay between saline water and fresh water and their effects upon the aquatic communities and the wetland development must be evaluated.

Streams

No stream channel relocation can be made without changing the length (and thus the gradient) and roughness of the channel. This in turn changes the velocity of flow and the energy available for channel erosion (degradation) and sediment transport. These changes may be controlled by designing the new channel, through the use of Best Management Practices, to provide significant beneficial impacts to the aquatic environment, particularly with regard to the fish, vegetative, and invertebrate communities.

Large sediment loads often develop to become the most destructive elements. Flowing water in all streams has energy. This energy is used to continually modify the channel by eroding, transporting, and depositing sediments until an equilibrium has been reached between energy and resistance. During equilibrium, stream channel changes occur constantly but the net flow of water and debris into and out of the system are equal. Total energy is influenced by the velocity of flow, which in turn is a function of the stream gradient, volume of flow, and the characteristics of the channel cross section and bed. It has been estimated that more than 95% of this energy is converted to heat by turbulence and bed and bank friction and lost. Only the remaining energy is available for eroding and transporting sediments.

If a reach of a stream is to be relocated, it must be designed so that the net inflow of water and sediment in the new section is the same as that in the older section or instability will result and detrimental channel changes will occur progressively both upstream and downstream. If the channel has been shortened, velocities will be increased and excessive erosion and transport of sediments will occur. Reduction in these velocities can be achieved through the use of check dams to reduce gradients, by placing obstructions such as boulders in the stream to increase the roughness of the channel, or by creating meanders. Roughness can be increased by providing vegetation, logs, sandbars or any other irregularities in the channel section. When a channel is lengthened, the gradient of a stream is decreased and deposition of sediment loads and local filling-in, or clogging, of the bed may result. Practices for minimizing the detrimental effects in this situation may involve re-designing the channel section so that the water flow has the capability to transport the sediment load through it.

All measures (BMPs) should ensure, as far as possible, that the relocated stream will be as stable, under the new conditions, as the original one, since an unstable stream will generally have a tendency to create subsequent environmental problems. It is imperative that any changes be followed by compensating Best Management Practices to minimize adverse effects of these changes. They must be designed to maintain, as closely as possible, the original channel's gradient, shape and width, alignment, and aquatic productivity, since these factors are all interrelated; and changing one has an effect on others. Channel slopes can be changed through installation of check dams made to look like natural features such as fallen logs. (See Photo No. 5-1). Width changes, particularly for the benefit of maintaining adequate depth of flow for aquatic life, can be minimized by providing dual-type channels (See Figure No. 5-1). The smaller, deeper channel on the left provides adequate depths for aquatic life during low flows. All of these practices are used to stabilize the stream regime and provide for the development and propagation of fish and wildlife native to the area.

Large boulders and cobbles placed into a channel increase its roughness, reduce the velocity of flow, and, at the same time, provide resting places or cover for fish and other aquatic life (See Figure No.5-2). These large rocks, placed on the outside of stream bends where velocities are high, can also act as rip rap to prevent bank erosion. They should be located so that they do not cause currents to impinge on the banks and create more severe erosion problems. severe erosion problem.

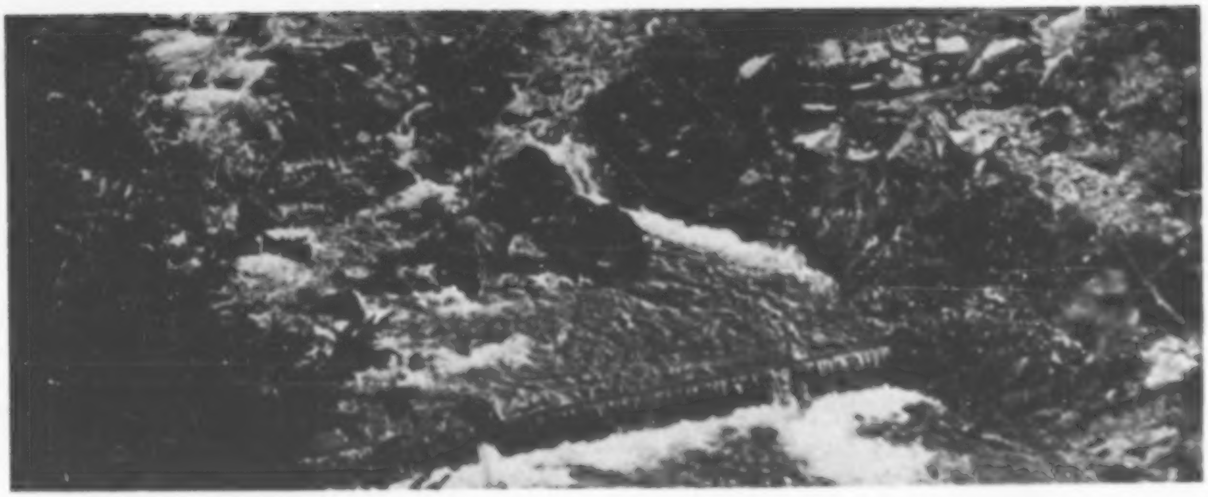


Photo No. 5-1 - Check Dam In Stream Provided To Decrease Its Gredient (U.S. Forest Service).

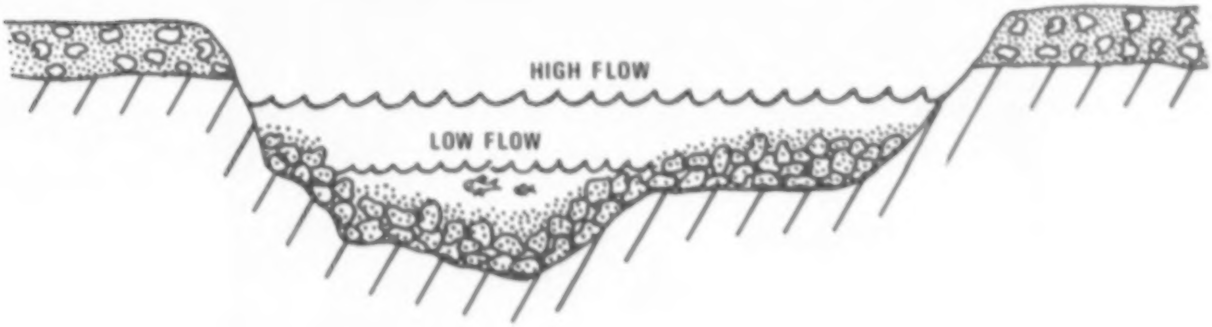


Figure No. 5-1 - Dual-Purpose Stream Channel Designed To Maintain Adequate Depth During Low Flows (After Reference No. 27)

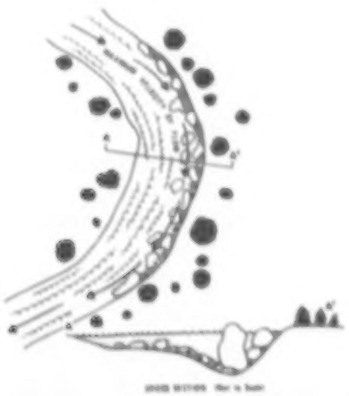


Figure No. 5-2 - Rocks Placed In Stream Section To Reduce Velocities and Prevent Erosion On The Outside of Bends (After Reference No. 27).

Deflector structures can be used to divert the water into more constrictive channels, to create pools, to simulate meander conditions, and to provide sufficient water depths during low flows. Rubble rock deflectors, log structures, and similar devices can be devised. Logs if properly used, can appear to be submerged, partially-buried fallen trees. They should be kept submerged permanently in order to prolong their life. Photo No. 5-2 illustrates rock rubble deflectors.

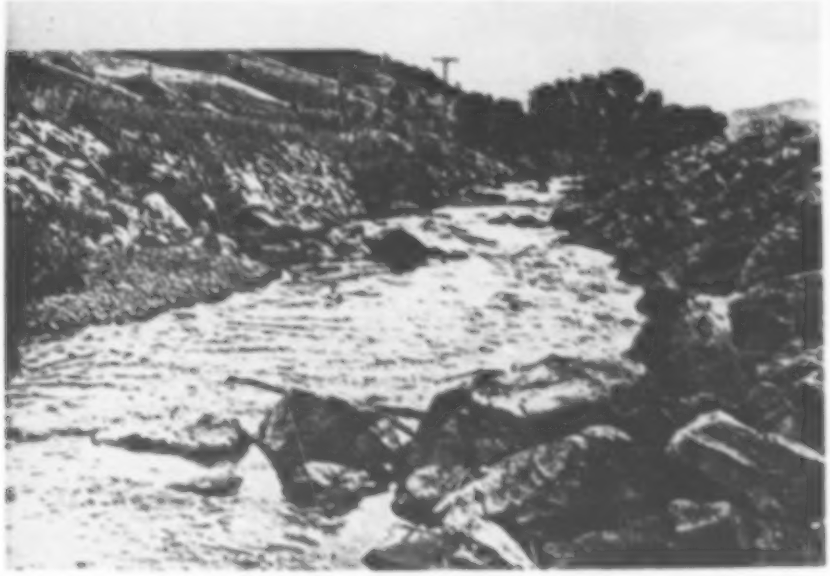


Photo No. 5-2 - Meanders Created by Rock Deflector Structures (Reference No. 27).

If a stream must be relocated or the channel section altered to make way for some type of development, the new channel should be designed and completely constructed, in accordance with projected hydraulic conditions, prior to diverting water into it. Extreme care should be taken to ensure that the existing stream does not receive excess sediment runoff from the disturbed new channel during construction. Measures and structures to minimize detrimental changes that will occur in the new channel should be in place before it receives the stream's flow and the old channel is plugged. All structures should have a natural appearance; and vegetation similar to that in the old channel area should be provided for the new one. The placement of additional soil may be required so that natural conditions are simulated to the extent needed for site replacement.

After the new stream channel has been in operation for a period of time, alterations such as acceleration of meanders or changes in depth may begin to occur. If they appear to be initiating subsequent environmental problems, additional structures, or other Best Management Practices similar to those initially designed for the channel, should be provided to control them.

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